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A SINGLE BID FOR DREDGING and deepening the East Channel of New York Harbor has been received by Maj. H. M. Adams, U. S. Engineer Corps, in response to his call for proposals to dredge some 60,000,000 cu. yds. in the proposed new Bay Ridge, Red Hook and East channels at the entrance to that port. According to the "Journal of Commerce," of New York, whose reporters interviewed a number of prominent local dredging contractors, the reasons they give for not bidding for the work is that it requires too great an outlay before beginning. The character and conditions of the work were stated briefly in our issue of March 30, 1899. The single bid which was received for the East Channel work was submitted by Mr. Andrew Onderdonk, of New York city, and the price bid was 9 cts. per cu. yd. for a contract of about 40,000,000 cu. yds. The bid stated that two dredges would be employed or more if they were demanded, and the specifications for the construction of the proposed machines were appended to the bid. Maj. Adams announces that the bid of Mr. Onderdonk will not be definitely passed upon until he has consulted with Col. Wilson, Chief of Engineers, U. S. A.

TWO POWERFUL SUCTION DREDGES, to be used in maintaining the channel in the South Pass, and also for work in the Southwest Pass, at the mouth of the Mississippi River, are being designed by Major James B. Quinn Engineer Corps, U. S. A., in charge of that district. They are to cost not more than $150,000 each, and are modeled on the plan of the dredge "Reliance," long and successfully used in New York harbor. The "Reliance" is 157 ft. long, 37 ft. beam, 16 ft. depth of hold, has two propellers and a hopper capacity of 650 cu. yds. There are two centrifugal pumps, with 15 and 18-in. suction pipes, about 60 ft. long, suspended alongside the hull. Major Quinn gives the record of the "Reliance" as follows: Average cubic yards per load, 584.87; average time pumping this load, 48.6 minutes; average time pumping per day, 4 h. 58.4 m.; average time on bar per day, 5 h. 43.4 m.; average time from bar to dump, 3 4m.; average time dumping, 12.1 m.; average time returning to bar, 25.7 m.; average time dump to anchorages, 66.6 m.; anchorage to bar, 51 m.; average number of loads per working day, 6.73; average quantity dredged per working day, 3,936.6 cu. yds.; average rate per minute, 12.03 cu. yds. The new boats will also be fitted with shore-discharge pipes to deposit material over the levees.

A DAM AND LOCK at the mouth of Bayou Lafourche, on the Lower Mississippi River, is being again discussed, as a means of reducing the cost of levee maintenance in the Lafourche district by cutting out the rise in the main river. Mr. S. F. Lewis, Assistant Engineer in charge of the district, says, in the New Orleans "Picayune," that such a plan could be carried out; but the levee system is efficient, as it exists, and the dam would convert the bayou into stagnant water and interfere with the supplies now sent down the bayou in steamboats. The dam would only cost about $20,000; but the locks would be expensive. To bring the 69 miles of double levee, along Bayou Lafourche, up to 3 ft. above the highest water at Donaldsonville, at the mouth of the bayou, and to 1½ ft. above at Lockport and lower points, would require about 2,135,000 cu. yds. of embankment. The two crevasses of 1898 occurred in a late extension of the levee district where the levees are still unimproved. No damage occurred to the improved sections.

THE "WILLIAM PRICE HOPPER" DREDGE, lately built by Wm. Simons & Co., of Renfrew, Scotland, for the Karachi Port Trust, of India, has the following general dimensions: Length, 236 ft.; beam, 42 ft. 6 ins.; depth of hold, 16 ft.; hopper capacity, 1,250 tons. The dredge is propelled by two sets of triple-expansion engines, of about 1,500 I. HP., and her loaded speed is 10 knots. The dredging is done by an endless chain of buckets working through a central well, with the usual steel-framed tower at the movable end of the dredge-ladder, for graduating the position of this ladder to the work to be done.

THE ATLANTIC CONSTRUCTION CO., through its attorneys, Wayne MacVeagh and F. D. McKenney, of Washington, has instituted two suits in the Court of Claims to recover a balance in excess of $250,000 alleged to be due for work done in the improvement of Savannah Harbor and Cumberland Sound. This is the work which was in charge of Capt. O. M. Carter, U. S. Engr. Corps, who was court martialed for his connection with it, and the testimony in this trial is still before the U. S. Attorney-General and unacted upon by him and by the President. The contracting company alleges that it performed this work under a contract of Oct. 8, 1898, made with the government and duly approved by the Chief of Engineers; that the United States was greatly in arrears on Oct. 9, 1897, when work was stopped; and that on July 11, 1898, Congress appropriated a further sum of $450,000 to continue these improvements. The disbursing officers of the government have withheld from the contractors the sum claimed as due, and hence these suits. The contracting company says that on the payments of the amounts due for work performed it stands ready to complete its contracts.

THE MERCANTILE-MARINE SHIPBUILDING OUTput for the whole world for 1898, says U. S. Consul James Boyle, of Liverpool, is estimated at 1,893,000 tons, and Lloyd's returns show that of this total 1,367,570 tons gross were launched in the United iKngdom. This English output covered 761 vessels, of which only 17 were sailing ships, and it does not include 41 warships launched in 1898, and aggregating 191,555 tons displacement. Not counting warships, at the end of 1898 there were 584 vessels under construction in English yards, aggregating 1,401,087 gross tons. On Dec. 31, 1898, Lloyd's gives the following list of vessels and their tonnage on the mercantile-marine register of the United Kingdom:

Description.	Number.	Gross tons.
Steam	8,835	10,816,310
Sailing	11,567	2,552,543
Totals	20,402	13,368,853

Of the total steam tonnage 98.4% were built of steel and 1.3% of iron. According to Lord Inverclyde, president of the Cunard Co., the gross earnings of steamships are now about $58.39 per ton, where they used to be $72.99 per ton. This reduction is due to the present keen competition. The same authority says that the cost of cargo steamers was now between $29.19 and $34.06 per ton of dead weight carried. Eleven reserve merchant cruisers annually receive from the British government $236,511 in subsidies.

THE EXPLOSION OF A LOCOMOTIVE BOILER near Hastings, Me., on April 19, caused the death of three men. The engine was one of several employed by the Hastings Lumber Co., to transport logs from the woods to the landing. At the time of the accident the engine was returning to the woods with one empty car and a crew of four men. While the engine was an old one it was considered in good condtion and no cause for the accident can be assigned.

THE EXPLOSION OF A 20-HP. BOILER near Chippewa, Wis., on April 15, killed three men and seriously injured five others. The boiler formed part of the equipment of a small lumber mill.

A QUANTITY OF BENZOL EXPLODED at the Fleers Chemical Works, Philadelphia, Pa., on April 25, instantly killing two men and injuring fully 20 others. Reports state that considerable quantities of benzine, benzol and gasoline were used in the works to produce flavoring for chewing gum, and the fumes of these volatile liquids reached the boiler furnace, ignited and thus caused the explosion.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Chicago, Burlington & Quincy R. R., seven miles west of Aurora, Ill., on April 20. The engine of an express known as the "St. Paul Flyer" left the track while moving at a speed of 50 miles per hour, and was followed by the whole train, which turned over and was partially burned. One person was killed and three others were injured.

INCENDIARY FIRES are reported to have killed 31 persons and made 2,000 others homeless at Pointe-a-Pitre, the chief town of the island of Guadaloupe, in the West Indies. United States Consul Ayme reports that 400 houses were consumed, and that the loss is estimated at fully $1,000,000.

A FIRE ON THE CHICAGO RIVER occurred April 17 and did considerable damage to the Chicago & Northwestern Railway bridge at Kinzie St. and the docks in the neighborhood. It is supposed that an exceptionally large accumulation of oil, naphtha or other inflammable refuse was set on fire by a lighted match or cigar thrown into the river. The fire extended up one of the sewers and burst through the street manholes. Railway traffic was blocked for some hours.

A NOVEL METHOD OF TESTING AIR-BRAKES is in use on the Northern Pacific Ry. After a train reaches the foot of a long grade it is stopped and a car inspector passes along and feels of the tread of one wheel in every truck. Whenever a wheel is found cold he marks on the cylinder with chalk the letter "C" and also the first letter of the station where the wheel was tested. If a wheel is found extremely hot, above the normal, he marks it with the letter "H." If he has the opportunity to investigate, he ascertains the cause for the hot or cold wheel and makes the necessary repairs at that time. If he does not have time to make repairs, after ascertaining what the conditions are, he fills out a defect card, stating defects, and places that on the car, and as soon as the car can be reached at any inspection point the repairs are made. This system has been in use about eighteen months.

A FAST RUN was made by the fast mail train of the Chicago, Burlington & Quincy R. R., between Chicago and Burlington, Ia., on April 23. According to the press dispatches, the train left Chicago 28 mins. late, and reached Burlington 5 mins. ahead of time, having covered the distance of 206 miles in 190 mins. The train lost 12 mins. in stops and slow-downs, which makes the actual running time 187 mins. The train ran from Galesburg to Burlington, 43 miles, in 30 mins.

EXTENSIVE FREIGHT YARDS are being established near London (England) by the Southeastern Ry. In order to remove all through traffic from the city lines and thus allow of some greater facilities in the suburban traffic. At these yards all through cars for foreign lines, or interchange cars, will be cut out and made up into trains, which will be hauled to the yards of the other companies. This will greatly relieve the congestion of traffic at the London freight terminals. A new terminal station is also being established in the city for the exclusive use of the fast freight traffic in milk, poultry, fruit, vegetables, flowers and other perishable articles.

RAILWAY FREIGHT RATES on grain from Buffalo to New York have been fixed as follows by the Trunk Line Association, the figures including the elevator charges at Buffalo for transferring the grain from the boats to the elevators, giving 10 days' free storage if desired and loading it on the cars. Wheat, 3½ cts. per bushel; rye, 3¼ cts.; corn, 2¾ cts.; oats, 2½ cts. The charge on wheat, allowing ½ ct. per bushel for Buffalo transfer charges, is equivalent to about $1 per ton for the whole distance from Buffalo to New York, or if the route via the New York Central & Hudson River be chosen, a rate of 0.23 ct. per ton mile. The rate on corn is equivalent to about 0.18 ct. per ton mile. These rates are very little above the average rates on grain moved by canal last season, and the general advantages to the shipper of the railway service, as compared with the canal, is likely to leave small patronage for the canal boatmen.

A SINGLE-RAIL RAILWAY on the Lartigue system is the latest of the many projects for additional means of communication between Liverpool and Manchester (England), a distance of 30 miles. It is to be one of the often-heard-of, but never-yet-seen railways, having a regular speed of 100 miles per hour. Even 150 miles per hour is talked of, but the projector, Mr. B. F. Behr, sticks to steam as the tractive power. The Lartigue system has been used for an agricultural railway in Algeria and for a 10-mile railway in Ireland. It consists of a series of A frames, connected by a carrying rail on top and two rails on the sides. The engine and cars straddle this structure and have horizontal wheels running on the lower rails to steady the train.

THE PENNSYLVANIA BILL TO PREVENT THE POLlution of water supplies passed the legislature just before adjournment and awaits disposition by the Governor. As it now stands, pollution by human excrement, only, is prohibited, as was stated in an editorial note in our issue of April 13; but the bill has been amended so that instead of applying to all the municipalities in the state it applies only to cities of the first class, or to Philadelphia. This is the outcome of two ambitious measures introduced at the opening of the legislative session, one prohibiting all pollution of public water supplies and the other appropriating $30,000 for a sanitary survey of the waters of the state. These two bills were discussed editorially in our issue of March 16, 1899.

THE NEW ELEVATED WATER TANK AT JACKSONVILLE, FLA.

By R. N. Ellis, C. E.*

The accompanying detail drawings and perspective view illustrate an elevated water tank for the Jacksonville, Fla., water-works, which was completed under direction of the writer in May, 1898.

The tank is located on the north side of the water-works grounds. These grounds are located in the center of the city, and are laid out as a park. It was, therefore, necessary to make the structure as sightly as possible, to harmonize with its surroundings. Having made note of a suggestion made by Mr. F. C. Coffin, in Engineering News (March 16, 1893), a few years ago, I determined to adopt the lines suggested by him. The details of the trestle and tank are shown by Fig. 1, and a view of it by Fig. 2.

In designing the trestle all lattice members were avoided, solid or built-up members being used, put together so as to present plane surfaces, easy of access for cleaning and painting.

The foundations of the tower consist of ten piers, the dimensions of which are shown in Fig. 2. The first 18 ins. of the piers are composed of Portland cement-concrete, formed of 1 part of cement, 3 of clear sharp sand, and 5 of broken stone; bedded in this concrete are two sets of 50-lb. steel rails. The brick work above the concrete is of hard burnt brick laid in Portland cement mortar, 1 of cement to 3 of sand.

The trestle above foundations is 100 ft. in height 65 ft. in diameter at base, and 30 ft. at the top. It consists of ten posts in five sections, composed of four 6-in. Z-bars with web plate. At the base and junction of the sections of posts 8-in. I-beams are set horizontally, and each panel is braced by diagonal tie-rods. The trestle supports a tank 30 ft. in diameter and 45 ft. in depth of side, with a conical-shaped bottom; in the center of the bottom is a 20-in. inlet and outlet pipe. A special shaped casting is riveted to the bottom of the tank, to which is attached the expansion joint. This joint is of cast iron, turned off and covered with a brass sleeve 3-16-in. in thickness. The gland of the stuffing box is of brass, trimmed off smooth. The stuffing box is of cast iron. From the expansion joint to the base casting the pipe is of wrought iron. The base casting has three outlets, viz.: 20, 16 and 8 ins. in diameter. Two sets of rods stay the supply pipe.

Around the base of the tank is a balcony, 3 ft. in width, supported on steel brackets riveted to the posts. It has a metal handrail and a wooden floor. From the ground to the balcony is an iron stairway of appropriate design with substantial hand-railings. From the balcony to the top of the tank on the outside, and from the top of the tank to the bottom on the inside are stout iron ladders set off 8 ins. from the side of tank. Around the top of the tank is a circular track bolted to brackets, and provided with a two-wheel trolley to be used in painting tank, etc.

The top of the tank is covered with a conical roof of galvanized wrought iron, 1/8-in. in thickness, riveted together and supported by an angle iron frame finished with four gables, finial and cresting, with door in gable where ladder is placed. The other gables have galvanized iron slats with fine copper wire cloth over them to keep out insects. The upper half of the ball of the finial is covered with galvanized iron; the lower half is open, a 2,000-c. p. enclosed arc light, burning 100 hours without trimming, is suspended in this ball by a wire rope in such a way as to be lowered down to the bridge over the tank for trimming. The current is carried to the lamp by two lead encased cables.

All parts of the tower and tank are constructed of steel. The steel used in the posts and struts is what is usually designated as high steel, having an ultimate strength of 75,000 lbs. per sq. in., with a minimum of 70,000 lbs.; an elastic limit of 40,000 lbs., an elongation of 20% in 8 ins.; and a reduction at fracture of 40%. Soft steel was used for tank plates, butt straps, tie-rods and rivets, having an ultimate strength of 60,000 lbs. per sq. in., with a minimum of 56,000 lbs.; an elongation of 25% in 8 ins.; and a reduction at fracture of 50%. A sample bar was bent 180°, and closed upon itself without showing any fracture, crack, or flaw on the outside of the bent portion. The bottom plates of the tank are 1/2-in. thick. The side plates range from 1/2 to 1/4-in. in thickness.

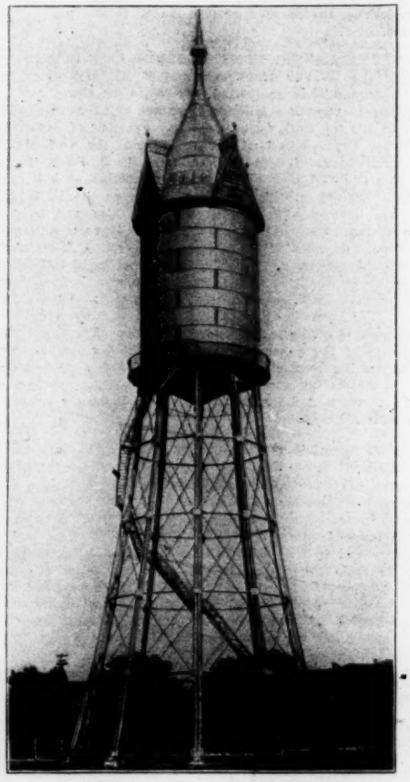

Fig. 1.—View of Elevated Steel Water-Tank, at Jacksonville, Fla.
R. N. Ellis, Engineer and Superintendent.

The workmanship was first-class. All surfaces coming in contact were thoroughly cleaned and painted before being riveted up. All holes were punched 1-16-in. small, and reamed in position, all work being fitted in the shop so that there was no straining of material by the use of the drift pin to make holes match. One coat of red lead and best linseed oil was given to all work before shipment; a second coat of red and white lead and linseed oil was applied after erection; and a finishing coat of white lead and oil tinted silver gray was given to complete the painting.

A recording gage with high and low water alarm is located in the pump-house, and connected to the tank by a 3/4-in. galvanized pipe. The tank is perfectly tight, and has been in use since May, 1898.

Mr. W. A. Macduff, of Jacksonville, built the foundations, and R. D. Wood & Co., of Philadelphia, the structure above the foundations. The cost of the foundations was $1,356; of the trestle, tower, tank, etc., $11,300; making the total cost of the structure $12,656.

Photographic copies of the plans were sent out with specifications when we asked for bids. Although the prints were small we received 16 bids, only one party objecting to making a bid from them. I think that photographic copies, 8 × 10 ins., with scale, would in most instances do as well to make bids from as large scale drawings.

*Superintendent Water-Works, Jacksonville, Fla.

COMPOUND LOCOMOTIVES ON THE NORTHERN PACIFIC RY.*

The record of the compound locomotive on the Northern Pacific Ry. is of interest on account of the number of different systems of compounding employed, and the different sizes and types of locomotives compounded, as well as the wide variation in the topography of the road over which they are run, and the kind of service in which they are employed. Through the courtesy of Mr. Wm. Forsyth, Superintendent of Motive Power of that road, the following particulars have been obtained.

Description of Compound Locomotives.—The systems of compounding include the Vauclain four-cylinder type, built by the Baldwin Locomotive Works, and the two-cylinder type as built by the Richmond Locomotive Works, the Pittsburgh Locomotive Works, the Brooks Locomotive Works and the Schenectady Locomotive Works. The principal dimensions of these engines, and of the simple engines with which they can be compared, are given in Table No. 1. This comparison, to be of value, must be made understandingly, as it will be noted that in no case is the simple engine in all respects like the corresponding compound.

The D-3 and F-1 compound engines are the same as the D-3 and F-1 simple engines, except in the cylinders and other compounding features. They are, in fact, the same engines with compound cylinders attached in place of the original simple cylinders, and the boilers strengthened to carry 180 instead of 150 lbs. of steam. The D-5 compounds are identical with the same class of simple engines, except in the cylinders and other compounding features, all the engines of this class, both simple and compound, having new boilers carrying 200 lbs. The simple engines, however, were only worked at 180 lbs. The Class P compounds are also identical with the corresponding simple engines, except in the cylinders and other compounding features. The changes from simple to compound, even if the engine is otherwise identical, make the compound heavier by the additional weight of cylinders. These excess weights are estimated in the table.

These compound engines displaced simple engines of various types and weights as follows:

The D-3 mogul compounds replaced similar simple moguls carrying 150 lbs. of steam.

The D-5 moguls replaced D-3 moguls carrying 150 lbs. of

*Abstract of a paper read before the Western Railway Club in March, by Mr. Edwin M. Herr, formerly Superintendent of Motive Power of the Northern Pacific R. R.

TABLE I.—Dimensions of Compound and Simple Locomotives; Northern Pacific Railway.

Class	Date first in service.	Builders and change in style of compound.	Type of comp.	No. of engines.	Cylinders—Diam. H.p. ins.	Cylinders—Diam. L.p. ins.	Cylinders—Strk. ins.	Boiler—Gr'te surface, sq.ft.	Boiler—Heating surf. Fire-box, sq.ft.	Boiler—Heating surf. T'bs, sq.ft.	Boiler—Heating surf. T't'l, sq.ft.	Boiler—Diameter shell, ins.	Engine dimensions—Diameter Driv. whls, ins.	Engine dimensions—Diameter Truck whls, ins.	Wheel base, eng. Rigid, ft.ins.	Wheel base, eng. Total, ft.ins.	Wheel base, and tender, ft. ins.	Weights in working order—On driv'rs, lbs.	On truck, lbs.	Total engine, lbs.	Total, eng. & tender, lbs.	Steam pressure, lbs.
D-3	1-97.	[1]Baldwin simple to Richm'd comp.	2-cyl.	1	19	29	24	16.77	130	1,419	1,549	56	56	30	15	3 23	4 45	3	85,900	18,500	104,400	175,300	180
D-3	1-97.	" " " Pittsburg "	2 "	1	19	29	24	16.77	130	1,419	1,549	56	56	30	15	3 23	4 45	3	85,900	18,500	104,400	175,300	180
D-3	1-97.	" " " Baldwin "	4 "	1	13	22	24	16.77	130	1,419	1,549	56	56	30	15	3 23	4 45	3	85,900	18,500	104,400	175,300	180
D-3	1-97.	" " " Brooks "	2 "	1	19	27	24	16.77	130	1,419	1,549	56	56	30	15	3 23	4 45	3	85,900	18,500	104,400	175,300	180
D-5	11-97.	" " " Schnectdy "	2 "	1	19	30	24	18.4	145	1,601	1,746	58¼	56	30	15	8 23	9 45	3	102,000	18,500	120,500	191,500	200
F-1	9-96.	[2]Baldwin simple to Baldwin "	4 "	3	15	25	28	35.3	167	2,154	2,321	72	50	30	14	0 22	3 49	2	138,000	20,000	158,000	235,600	180
P	6-97.	[3]New Schenectady compound.....	2 "	9	22	34	26	30.8	203	2,332	2,535	62	69	33	14	10 25	10 52	2	112,000	43,500	155,500	249,500	200
R	8-97.	[4]New " " 2	"	20	22	34	26	34.2	240	2,655	2,895	70	63	30	14	10 25	11 52	9½	126,000	46,500	172,500	264,500	200
S	5-98.	[4]New " " 2	"	8	22	34	28	34.2	240	2,655	2,895	70	63	30	14	10 26	3 53	1½	131,800	42,000	173,800	265,800	200
X	2-97.	[4]New " " 2	"	4	23	34	30	35.0	222	2,722	2,944	72	55	28	15	6 26	4 53	8	150,000	36,000	186,000	270,700	200
Y	11-98.	[4]New " " 2	"	14	23	34	34	35.0	222	2,706	2,928	72	55	30	14	8 23	3 51	9½	166,000	20,000	186,000	298,000	210
		Simple Locomotives with which above Compounds can be Compared.																				
D-3.		[1]Baldwin		95	18	..	24	16.77	130	1,419	1,549	56	56	30	15	3 23	4 45	3	85,000	15,000	100,000	170,900	150
D-5.		[1]Baldwin with new boiler		3	18	..	24	18.4	145	1,601	1,746	58¼	56	30	15	8 23	9 45	3	93,600	15,000	108,000	179,600	180
F-1.		[2]Baldwin		29	22	..	28	35.3	167	2,154	2,321	72	50	30	14	0 22	3 49	2	135,000	15,000	150,000	227,600	150
P.		[3]Schenectady.		9	20	..	26	30.8	203	2,332	2,535	62	69	33	14	10 25	10 52	2	110,000	38,000	148,000	242,000	200

Style: [1]Mogul; [2]Mountain consolidation; [3]Ten-wheel passenger; [4]Ten-wheel freight; [5]Mountain mastodon; [6]Mountain consolidation.

steam; but as the D-5 moguls are both simple and compound, a comparison is made between these engines as well as between each of them and the simple D-3 moguls carrying 150 lbs. of steam which they replaced.

The F-1 mountain consolidation engines partly replaced similar simple mountain consolidation engines, and one of them also was run in the same service with the mountain mastadon compound engines, Class X. A comparison with both is therefore given.

The Class P passenger ten-wheel compounds replaced simple ten-wheel passenger engines, but as the latter were very much lighter (weighing only 81,000 lbs. on drivers, with much smaller boiler and lower steam pressure than the Class P engines), no comparison of value can be made.

per hour eastbound and 17.5 miles per hour westbound; between the two latter at 17.7 and 13 miles respectively.

The Class P engines are used in passenger service exclusively, those shown in Fig. 5 running between Spokane and Ellensburg. This is a continuous run of 273 miles with heavy trains of 10 to 15 cars, stopping at nearly all stations, and in the summer and fall loading large quantities of express matter. In 1897 the train was carded 28.7 miles per hour westbound, and 32.7 miles per hour eastbound. Early in 1898 speed was increased to 29.5 westbound, and decreased to 30.3 miles per hour eastbound. The engines in this service make about 8,600 miles per month and all are either double or triple crewed.

The F-1 and X engines are used exclusively as mountain

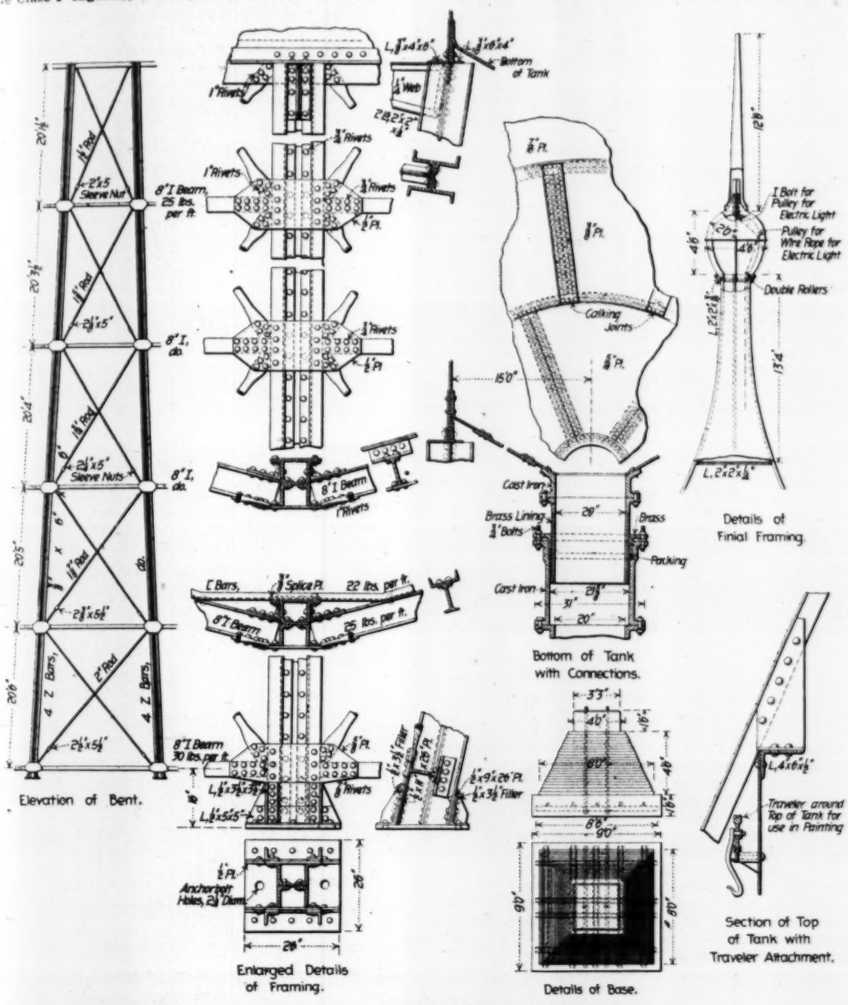
Elevation of Bent.
Enlarged Details of Framing.
Bottom of Tank with Connections.
Details of Base.
Details of Finial Framing.
Section of Top of Tank with Traveler Attachment.

FIG. 2.—DETAILS OF ELEVATED STEEL WATER-TANK, AT JACKSONVILLE, FLA.

Comparison is made only between the simple and compound engines in the same service.

The Class R engines also have no comparable simple engines, and are therefore shown on two districts of the same division differing considerably in grades.

The Class S and Class Y engines have so recently gone into service that no details as to their performance are shown.

The Class X engines replaced simple F-1 mountain consolidation engines carrying 150 lbs. of steam. They are also compared with the compound F-1 mountain consolidation engines carrying 180 lbs.

Character of Service.—The D-3, D-5 and R engines are all in through freight service on divisions where little local business originates, and therefore are called upon to do but little switching. The D-5 engines have more switching to do than the other two, but even they are required to do comparatively little. The trains the latter draw are carded to make 14.6 miles per hour eastbound, and 16.3 miles westbound. Those hauled by the D-3 compounds are carded 13.2 miles per hour eastbound, and 13.7 miles westbound, all on single track with frequent meeting points. The Class R engines on the second and third districts of the Idaho division, between Spokane and Pasco, and Pasco and Ellensburg, were generally used on express freight trains carded between the two former points at 15.3 miles

helping engines. The data given in Fig. 6 for these engines is on Helena mountain (Profile E, Fig. 2). This is the grade where the main range of the Rocky Mountains is crossed and on the east side is continuous 2.2% for 18 miles, with much curvature as sharp as 10°. Speed is low, from 4 to 12 miles per hour on the up grade. Table 3 also gives the result of tests with these engines on Bozeman mountain near Livingston (Profile F). The grade and curvature are about the same, 2.2% maximum, and 10° as on Helena mountain, but the length is only about 12 miles instead of 18.

Grades and General Description of Line.—The profiles of the divisions referred to are shown in Figs. 1 and 2. The road is single track, and, excepting over mountains, runs through a more or less rolling prairie country almost devoid of trees and entirely so of forests or other obstructions to the winds, which in northern Minnesota (Profile B) and eastern Montana (Profile A) often seriously interfere with the movement of trains. The winter temperature in these districts is very low, often ranging between 0 and 20° below zero for weeks, while the winds cause the locomotive performance to suffer, not only from their

TABLE II.—Mileage and Repairs of Compound and Simple Locomotives; Northern Pacific Ry.

Engine.		Engine miles.	Gross ton-miles.	Repairs per engine mile.	Repairs per 1,000 G.T.M.
A.—Mogul Engines; April 1, 1897, to Sept. 30, 1898.					
Compound	A	56,886	42,149,900	$.0161	$.0217
"	B	60,234	49,070,628	.0154	.0182
"	C	54,497	42,404,236	.0154	.0198
"	D	51,248	40,544,366	.0121	.0153
Simple	507	52,915	31,400,344	.0166	.028
"	520	63,234	38,163,393	.012	.0199
"	566	52,738	34,612,835	.0184	.0284
B.—Mogul Engines; Jan. 1 to Sept. 30, 1898.					
Comp., D-5,	No. 410	19,357	22,879,392	$.0138	$.0116
Simple, D-5,	" 430	23,835	27,697,742	.013	.0112
" D-5,	" 431	24,215	25,493,019	.0148	.0141
" D-5,	" 432	20,858	24,051,100	.022	.0191
C.—Ten-Wheel Compound Freight Engines; July, 1897, to September, 1898.					
Class R,	No. 170	70,255	69,901,091	$.019	$.0191
" "	" 171	70,151	70,411,387	.0186	.0186
D.—Ten-Wheel Passenger Engines; June, 1897, to Sept. 30, 1898.					
Comp., Class P,	200	106,473	57,450,095	$.0226	$.042
Simple, " "	220	95,347	50,361,863	.0228	.0431
E.—Consolidation and Twelve-Wheel Compound Engines; May 1, 1897, to Sept. 1, 1898.					
Class X, 12-Whl.,	No. 13	27,159	17,328,907	$.0307	$.0521
" " "	" 14	30,950	19,231,253	.028	.046
" " "	" 15	32,323	19,717,432	.0236	.0383
" " "	" 16	29,496	18,802,336	.0284	.0451
Comp., Consol., Cl. F-1		27,997	15,315,493	.028	.0513

own force, but in winter from the obstruction of the track by drifting snow. It should be stated, however, that the winter of 1897-98 was an exceptionally mild one in these regions, and but little difficulty was had either with cold or snow.

In districts shown on Profiles C and D, between Spokane and Ellensburg (in Washington), the winters are generally mild, and but little snow or wind is experienced. Over the mountain districts, Profiles E and F, while the winters are cold, no large amount of snow falls, and high winds are almost unknown.

Performance of Compounds.—The performance of the locomotives is determined by the number of pounds of coal consumed per 1,000 ton-miles of train hauled, including the engine and tender, and if of a freight train the caboose also. As the size of the train hauled has a very considerable effect upon the performance figured as above, the weight of the average train hauled is shown on the monthly performance sheet.

Fig. 3 gives the average performance, average train and economy of the four converted Class D-3 mogul compounds over the simple Class D-3 locomotives on the first district of the Montana division between Billings and Livingston (Profile A). The average performance of the four compounds is shown in full lines, and the average performance and average train of all the simple Class D-3 locomotives running in the same service on this district are shown by dotted lines. The performance of each individual compound of the four different types is shown in Fig. 4, with the same curve of average performance of the simple engines in dotted lines as is shown in Fig. 3. An examination of each of the lines will show that no one compound shows uniformly the best performance, although

TABLE III.—Comparative Tests of Compound and Simple Locomotives; Northern Pacific Ry.

	Twelve-wheel compounds.			Consolidation simple.
Engine No.	14	13	16	494
Train, tons behind tender	538.24	310.12	487.91	451.02
Speed from indicator,* District A	16.9	21.8	19.30	17.70
Drawbar pull from dynamometer, District A	8.03	6.76	7.31	6.58
HP. from dynamometer, District A	687.5	757.8	710.30	596.90
HP. from indicator, District A	898.9	1149.2	1091.50	875.20
Speed from indicator,‡ District B	8.3	12.3	10.90	11.0
Drawbar pull from dynamometer, District B	12.77	10.23	11.06	10.48
HP. from dynamometer, District B	573.2	628.0	594.20	594.20
HP. from indicator, District B	765.9	946.7	864.50	851.40
Coal used	Chestnut.	Red Lodge.	Red Lodge.	Red Lodge.
Evaporation per lb. of coal, total run	....	....	....	....
Actual	5.95	4.81	5.83	4.08
From and at 212°	7.20	5.85	7.10	4.97
Ton-miles per lb. of coal; total run	1.763	1,388	1.729	0.996
Coal per 1,000 ton-miles, lbs.; total run	572	731	585	1,081

*Engine No. 14 ran from Helena to Blossburg (Fig. 2), District A being from Helena to Mile 7½, and District B from Mile 7½ to Blossburg.

‡Engines Nos. 13, 16 and 494 ran from Livingston to Muir (Fig. 2), District A being from Livingston to Mile 6, and District B from Mile 6 to Muir.

compound D makes considerably the best average. This compound was always operated without using high pressure steam in the low pressure cylinder to start the train, and, while, as the diagram shows, the economy was good, frequent delays and stalling in different places caused this feature to be seriously criticised by the operating officers. Of the relative economy of the others, all of which used high-pressure steam in the low-pressure cylinder when starting, it would be difficult to choose. The average train each month is not plotted, owing to the confusion of lines, but the general average of the trains hauled during the seventeen months is shown.

Profile A (Fig. 1) shows that the work westbound on this district is continuous and almost uniform, the road gradually ascending 1,375 ft. in 115 miles. This is quite a favorable section for the compound, although not as favorable as a division where the engine can be more nearly fully loaded each way.

None of the compounds had been through the shop since they were converted, and it is interesting to note that the economy was well maintained until September, 1898, when they had averaged nearly 90,000 miles each; although in the last few months shown, the performance of

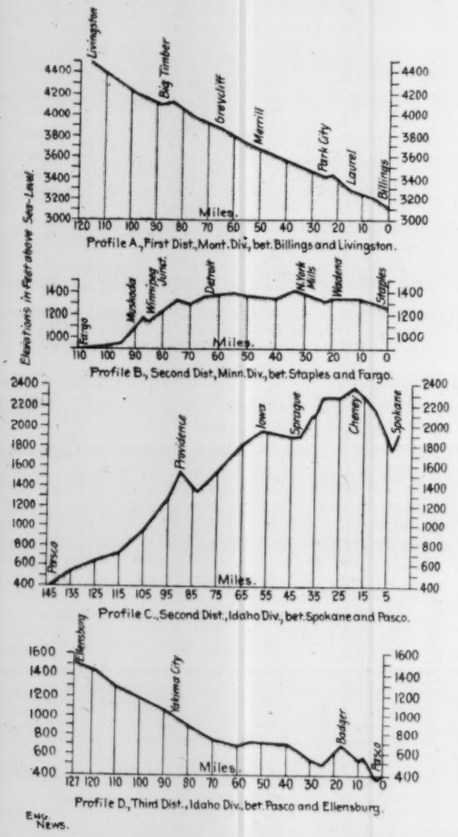

Fig. 1.—Profiles of Four Divisions of the Northern Pacific Ry., Operated by Compound Locomotives.

the compound does not compare as favorably as in the early part of their service.

The cost of running repairs, with the mileage made between April 1, 1897, and Sept. 30, 1898, for compound and simple engines compared with them, is given at A in Table No. 2.

The second district of the Minnesota division, between Staples and Fargo, is very favorable to the compound, as will be seen from Profile B (Fig. 1), especially when it is explained that at Winnipeg Junction the traffic from the Manitoba division meets the main line, enabling trains to be filled up at this point in both directions. The record of the compound here is quite remarkable, averaging 28.4% economy over the simple engines of the same class carrying 180 lbs. steam pressure, and 35.7% economy over the lighter moguls carrying 150 lbs. It should be noted that the compound hauled somewhat heavier trains than the simple, and very decidedly heavier than the D-3 engines, which would assist in improving its economy compared with engines hauling lighter trains. The cost of running repairs for these engines can scarcely be compared in value with those of the D-3 engines, as the D engines have only made a total of about 30,000 miles each up to Sept. 30. The repairs of the compound and simple Class D-5 engines, all of which have been in service the same length of time, can be fairly compared from Jan. 1 to Sept. 30, 1898, and are shown at B, Table No. 2.

It should be stated that owing to ballasting during the month of August, engine 410, the compound D-5, was laid up, as there was ample power without this engine, whose low-pressure cylinder caused trouble, striking ballast unloaded near the track. This accounts for the low engine mileage compared with the simple engines of the same class.

On the second district of the Idaho Division, between Spokane and Pasco, the performance of the Class R engines during the summer months of 1898 was not as good as during the corresponding months of 1897. This indicates that these compound locomotives, after making upwards of 70,000 miles in heavy service, were becoming less economical to the extent shown. Such a conclusion is, however, not entirely correct, as the quality of the coal used during the summer of 1898 was inferior to that used during the corresponding months of 1897, being in 1898 largely composed of fine screenings, while in 1897 lump coal from the same mines was generally furnished. After making the above mileage, at the average rate of about 4,400 miles per month, hauling trains averaging upwards of 1,000 tons on long stretches of 1% grade, it is not to be expected that the engines were as economical as when first put in service, and when the poor quality of coal used is considered their relative performance is good. The cost of running repairs on the Class R engines on the second district, with the mileage made between July, 1897, and September, 1898, as well as ton-miles hauled, is given at C, in Table No. 2.

In Fig. 5 is shown the performance of both the simple and compound Class P engines in passenger service between Spokane and Ellensburg. This, as before stated, is a continuous run of 273 miles, over two districts of the Idaho division, shown on Profiles C and D (Fig. 1). The coal record of the compound engine 200, together with the average train hauled by it, and the percentage of coal saved by it, over the simple Class P engine 220, are shown in full lines; the corresponding coal record and average train of the simple engine 220 being shown in broken and dotted lines. It will be noted that the average train hauled is upwards of 500 tons, and in the latter part of 1898 upwards of 550 tons. This means very heavy work on the second district eastbound, and on parts of this district westbound also. In only two months out of the fourteen for which we have comparative records did the compound fail to show economy over the simple. An investigation of the cause in each case, made at the time, brought out the fact that the compound locomotive in both these months happened to catch badly delayed trains, with which time was made up in bad weather and with a poor quality of coal, while the simple engine in these two months happened to catch trains more nearly on time and made up much less time. In July, 1898, the reverse conditions existed, resulting in an exceptional record in favor of the compound.

The average economy for the entire period, viz., 14.6%, is probably nearly what might be maintained. It must be remembered, however, that this can only be expected in rather unusually heavy passenger service. It will be noted that the smaller average train in the last months of 1897 and January and March of 1898 resulted in smaller saving by the compound, while with the increase of train after March, 1898, the relative economy of the compound improved. The record in the month of August, 1898, was made after the compound had made over 100,000 miles (the simple over 90,000 miles) in the above service with only ordinary roundhouse running repairs.

The average cost of repairs, together with mileage made and ton-miles hauled, from June, 1897, to Sept. 30, 1898, is given at D, in Table No. 2.

The simple engine making less mileage was at some disadvantage in the matter of repairs, but the indications are that as far as the running repairs are concerned the compound will cost no more. Both engines were always double, and often triple crewed, and the record of mileage repairs and performance clearly shows that no advantage in service or repairs was given the compound.

Fig. 6 shows the average performance of four compound mastodon engines, Class X, from April, 1897, to July 31, 1898, and also compound consolidation F-1 engines for the months of July, August and November, 1897, and simple consolidation F-1 engines for months of April, May and August, 1897. In order to avoid confusion of lines showing coal consumed and the average train, two base lines are used, the upper line being for the coal per 1,000 ton-miles, the lower for the average train in tons. It will be noted here that the coal burned per 1,000 ton-miles is much greater than in any service previously shown, amounting one month to 391 lbs. per 1,000 ton-miles for simple engines.

The performance of the F-1 compound is practically the same as the mastodon in coal per 1,000 ton-miles, and when the smaller average train hauled by the former is considered, the steam economy is undoubtedly better than that obtained by the heavier mastodon. The better economy of the four-cylinder compound in this service and not in the ordinary road service, when compared with the two-cylinder compounds, is doubtless due to the engines in mountain service being worked almost always so nearly full stroke that the cylinder ratio of the two-cylinder compound does not give expansion enough to reach the point of greatest economy, while the four-cylinder compound, having a larger cylinder ratio, more nearly approaches it. The profile of the part of the road upon which the performance in Fig. 6 was made is shown on Profile E (Fig 2), between Helena and Elliston. Fig. 6, like all the others, was plotted from the monthly performance sheets, and shows the performance of the engines for which the results are given in regular daily service over the sections of road indicated.

It is interesting in mountain service to compare the results of the up-hill work with the performance of locomotives running in both directions, and for this purpose, and also to still further compare the work of a simple and compound locomotive under various conditions, Table 3 is given.* Here are tabulated the results of a series of tests made by Mr. A. Lovell in April, 1897, of three of the four mastodon Class X engines, whose performance is shown in Fig. 6, and Class F-1 simple mountain consolidation engine 494. All tests, except one, that of Class X engine 14, were made from Livingston to Muir (Profile F); that of engine 14 from Helena to Bloss-

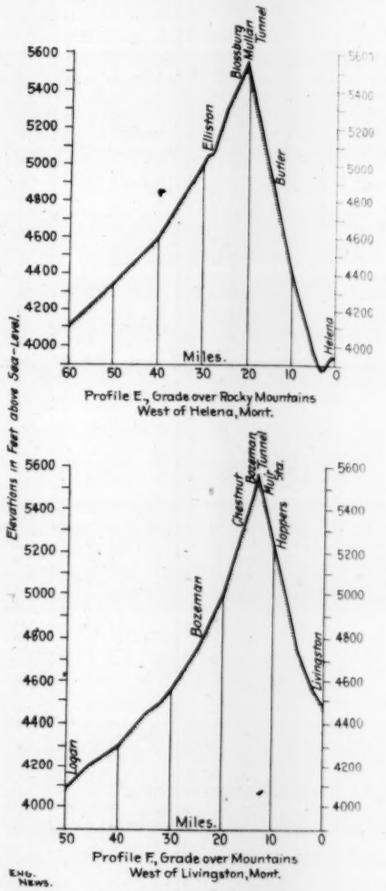

Fig. 2.—Profiles of Mountain Divisions; Northern Pacific Ry.

burg (Profile E). The grades are practically the same, 2.2% maximum, but in the former case the distance is 12 miles; the latter about 18 miles, with more curvature. The great increase in consumption of coal in all engines over that shown in regular up and down-hill work is very striking, the compound in one case reaching a consumption of 853 lbs. of coal per 1,000 ton-miles, the simple 1,339 lbs.

The cost of repairs for each of the mastodon Class X engines and the four-cylinder compound Class F-1, from May 1, 1897, to Sept. 1, 1898, is given at E, in Table No. 2.

All the Class X engines were originally furnished with cast-iron wheels under the tender. The brake service was so severe on this long 2.2% grade that it was found desirable on account of cracked plates to replace these with steel-tired wheels, which was done about Jan. 1, 1898. The cost of steel-tired wheels is not included in the above cost of repairs, nor is the cost of repairs on account of wrecks, but the expense incident to maintaining the cast-iron wheels on tender before they were replaced is included. With the exception of engine 13, which was derailed and turned over, none of these engines had $50 worth of work done on them on account of wrecks. They were held out of service on account of light repairs for from 3 to 52 days during the 17 months

*This table we have condensed, giving the averages of four trips for each engine.

for which the cost of repairs is given. Some of these periods may seem long, but the engines were located 123 miles from the nearest shop and upwards of 1,000 miles from a foundry and heavy forge shop, causing unavoidable delay to work requiring castings or heavy forgings.

The tests in Table No. 3 indicate about the quality of coal used at these points for locomotive purposes. It will be seen that the evaporative power of the Red Lodge coal varied considerably in the different locomotives tested, the compounds showing better evaporation than the simple. This is generally true and is one of the causes of the greater economy of this type of locomotive.

As the evaporative quality of the coal used must be

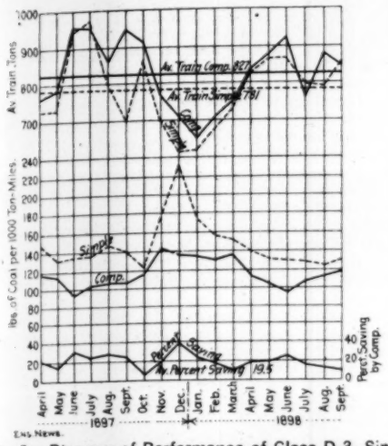

Fig. 3.—Diagram of Performance of Class D-3, Simple and Compound Mogul Locomotives, on First District, Montana Division, Between Billings and Livingston.

known before proper comparison can be made of the performance of locomotives burning different kinds of fuel, the evaporative values of all the principal coals used on the Northern Pacific Ry. locomotives, with the divisions on which each is used, is given in Table No. 4. The evaporative value is that determined in an elaborate series of tests of 27 different bituminous coals, made under stationary boilers and on both mogul and consolidation locomotives, by Mr. A. Lovell, then Engineer of Tests, Northern Pacific Ry., about two years ago, and supplemented by careful analysis and determination of the theoretical evaporative value. As the results obtained from the stationary tests are probably the most accurate, they are given, together with the theoretical evaporation from and at 212°.

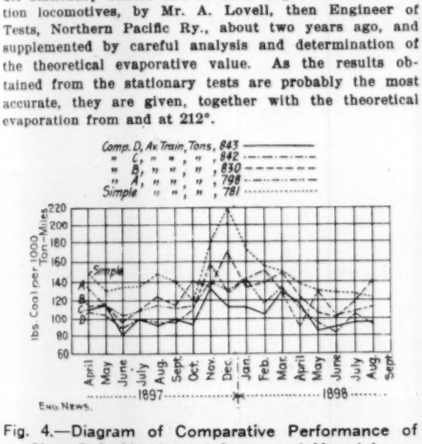

Fig. 4.—Diagram of Comparative Performance of Class D-3, Simple and Compound Mogul Locomotives, on First District, Montana Division, Between Billings and Livingston.

The Design and Maintenance of Compounds.—Many railway mechanical men, while freely admitting that the compound locomotive in heavy freight service will prove more economical in the consumption of coal than the simple engines of the same weight, boiler capacity, steam pressure and general design, give as their reason for not advocating the compound locomotive for such service, its liability to failure on account of breaking down, increased cost of maintenance and consequent longer enforced idleness. Were the failure of compound locomotives generally in the compounding features, and were such failures difficult to remedy, such objections to the use of such locomotives would have great weight. The intercepting and separate exhaust valve, where present, the receiver in the two-cylinder type, and the larger low-pressure cylinders are the peculiarly compound features. Investigation will show that the increased cost of maintenance and general unsatisfactory performance is not on account of broken intercepting valves, leaking receivers, or difficulty in packing or counterbalancing the low-pressure cylinder. Failures occur on account of broken frames, broken cylinders, unequal wear on the low and high pressure sides of the engine, broken piston rods, cut high pressure valves and consequent break-downs in the valve motion, cut and badly worn cylinders and other causes, practically all of which are clearly traceable to either bad design or construction, or improper care in maintenance.

It would seem an admission of inability to cope with the engineering problem of the design of the compound locomotive, or the administrative ability to care for a machine which is acknowledged to save a considerable proportion of the largest single item of expense on a railway, to refuse to use such a machine because it breaks down. Is it not rather the duty of railway mechanical officers to study the causes of failure in such machines, and by remedying such defects as developing in existing types, learn to design a compound locomotive so strengthened in the weak places and modified in those of impractical construction that it will not fail in service. This accomplished, a further careful observation and effort to learn how to so care for and operate this more economical machine will soon enable its cost of maintenance to be reduced, just as long years of practice and care have done in the repairs of the simple locomotive.

No one realizes more keenly than the writer, that the problems above referred to are by no means easy. The importance of knowing exactly what difficulties are experienced in regular operation and immediately applying some remedy for every defect cannot be too strongly impressed. The old adage, "A stitch in time saves nine," was never more apropos than in caring for a compound locomotive. It should be remembered in considering the above data that all of the compound locomotives, the performance of which is shown, have yet to receive their first general repairs. They are all comparatively new, but none have received any special consideration in the conditions under which they have thus far seen service; in fact, all master mechanics were instructed to put the compounds to the hardest test and always favor the simple engines in case conditions were not the same. Their performance in ton-miles indicates that these instructions have been carried out. The exact facts as to the general design, conditions of operation and the results obtained, both as to performance, fuel economy and running repairs, have, it is believed, been faithfully given.

FALL OF AN ELEVATOR IN CHICAGO.

One of the elevators on the Quincy St. side of the Great Northern Hotel, Chicago, fell on April 17, and the matter has been investigated, but no final conclusion has been reached. The elevator boy had just started the car down, when it ran swiftly to the bottom of the shaft, breaking the cables, but the boy (who was the only occupant) managed to get out before the cables fell and smashed the car. The Standard Elevator & Mfg. Co. claims that the accident was due to the fact that the automatic stop was out of order, and writes us as follows:

The automatic stop is a part of the machine proper, or is operated by it. The car could not have run away. If it had, it would have knocked out the tile pit, which is a very frail affair. These machines are run from 400 to 500 ft. per minute, and when the ram struck the buffer on the top of the hatchway, the car rebounded, the cables snapped, having been slackened by the rebound of the car, and probably pulled the cables through the clamps, as claimed by the city inspector, the automatic stop at the time being out of order.

The following is the substance of the report of the two inspectors who made the investigation for the Building Department:

The passenger elevator No. 4 at the Quincy St. entrance or side of the Great Northern Hotel is known as a vertical high-pressure hydraulic machine. It has a 10-in. cylinder, about 105 ft. long, geared at 2 to 1, which would leave the plunger 52½ ft. in cylinder; working pressure about 200 lbs. per sq. in.; speed, about 500 ft. per minute. There are six ½-in. hoisting cables. The automatic stops are constructed so that when the car reaches to within 12 ft. of its extreme travel both ways the pressure on ram is reduced and continues to decrease until the car stops.

The safety governor is so set that when the car travels at a greater speed than 500 ft. a minute the dogs will catch in the guide strips. We find that this car was on its downward travel, ram traveling upward, when one of the ⅝-in. rods of the automatic attachment broke, which threw the buffer to one side, thus preventing any cushion or decreased pressure on cylinder until the car came to the bottom of the shaft and allowing the ram to travel further at the greater speed than set for under full pressure, and also allowing the cables to pull through the clamps which hold them in position.

In view of the fact of the peculiar construction of the automatic gear, which differs from those in general use, we have recommended that the automatic stop rods be made larger and stronger and fitted up with guides fastened to the wall, which will prevent any more accidents of the same kind. The aforesaid recommendations apply to all elevators in Great Northern buildings. In conclusion we beg to state that it is absolutely impossible for any mechanic to discover the flaw in automatic rod or any weakness to rod which broke and caused the accident.

Elevators in Chicago hotels and buildings are apt to be in unsafe condition, according to a published statement of the Building Department. It is said that safety appliances are not kept in proper condition, and that the semi-annual inspections by the city are not sufficient to prevent this state of affairs. The owners of buildings, however, most unreasonably object to the payment of a $2 fee twice a year, and the city has sometimes to sue for the amount. In February, 1890, the safety appliances of the elevators in the Leland Hotel were found to be defective, and repairs were ordered, while the Gault Hotel has been ordered to stop operating its elevators until proper repairs have been made and have been approved by the city.

TABLE 4.—Coals Used on Locomotives; Nor. Pac. Ry.

Coal.	Division.	Evap. lbs. water per lb. coal and at 212°. Theoretical from analysis.	Evap. under sta. boil.	% Ash.—From analysis.	% Ash.—From sta. tests.
Youghiogheny	Minn., Dakota & Manitoba	14.351	7.59	7.95	10.07
Red Lodge	Yellowstone & Montana	10.926	7.18	9.04	13.66
Roslyn	Rky. Mts., Idaho & Pacific.	12.821	7.33	14.34	18.93
Chestnut	Montana	12.542	7.14	12.76	17.53
Hocking	Minn., Dakota & Manitoba	12.248	7.21	8.60	11.50

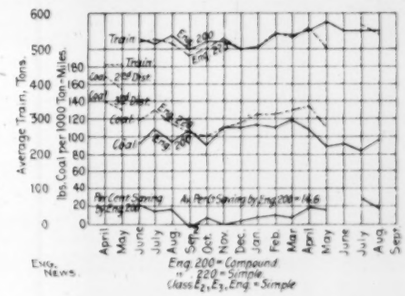

Fig. 5.—Diagram of Performance of Simple and Compound Ten-Wheel Passenger Locomotives, on 2d and 3d Districts, Idaho Division.

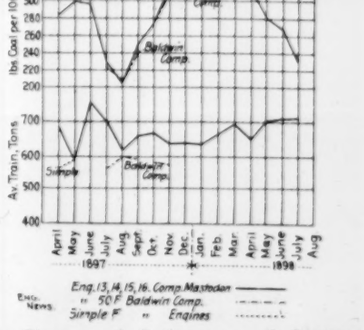

Fig. 6.—Diagram of Performance of Compound Twelve-Wheel and Simple Consolidation Engines, on Grade Over Rocky Mountains.

NOTES FROM ENGINEERING SCHOOLS.

Missouri School of Mines and Metallurgy.—Mr. Geo. E. Ladd, Director of this school, writes that the entrance fee of $10, formerly required for the courses in mining, metallurgy, chemistry, civil engineering and general sciences, has been abolished. The school forms one department of the Missouri State University, at Rolla, Mo.

New York University.—The School of Civil Engineering has been reorganized and merged into a School of Applied Science, which will commence by offering four courses, namely, Civil, Mechanical and Chemical Engineering and Industrial Chem-

istry. The resources of the Department have been increased to a yearly income of $25,000. The work will go forward for the present in temporary wooden pavilions and such new buildings as have been erected at the University's new site, north of the Berkeley Oval.

Columbia University.—A course in Commerce is probably to be established at Columbia University through the co-operation of the New York Chamber of Commerce. Two plans are being discussed: One proposes a four-year course of 15 hours per week, with 52.3% of the total time given to distinctly commercial subjects. The second plan proposes that 34% of the total time be given to these subjects. The first plan takes up the matter mainly from the point of view of the political economist, and would turn out men highly specialized and better fitted to solve particular problems of distribution, etc. The second plan would pay more regard to the equipment of the student, and afford a broader general training, in production, commercial chemistry, etc. A grant of $10,000 to $12,500 a year would carry out the first plan; and $20,000 would cover both the collegiate and the graduate courses now outlined. The second plan would involve an expenditure of about $12,000 per year; with certain amounts added to both for the purchase of charts and illustrative material.

INSPECTION OF INTERLOCKING PLANTS.*

By W. H. Elliott.†

The apparent lack of any definite instructions or systematic requirements in the method pursued by the different roads in the inspection of interlocking plants is the occasion of this paper being written. If a plant has been inspected, it is certainly highly important to have the inspection made in such a way as to determine definitely that the plant is in a safe working condition so far as it is practicable to have it. But unless definite instructions are laid down by the signal department as to what shall constitute a safe working condition, how can this be determined? Surely it is not a matter that should be left to the individual opinion of each inspector.

Replies received from most of the roads having signal departments, in answer to a letter asking for information in regard to their method of inspection and reporting, show that but one road, so far as could be ascertained, requires a detailed report. Nearly all the roads of whom inquiries were made have men whose duty it is to inspect regularly the interlocking plants, and are responsible for their condition; but the methods of inspecting are left very much to the discretion of the individual, and consists, for the greater part, of an examination of the physical condition of the connections, which are not likely to get out of order or to change. But few require a test to be made of the locking conditions at switches and derails, and none of them say definitely what shall be considered good and what unsafe. Reports to the signal engineer, or superintendent, as a rule, simply state that a certain plant was inspected, and refer only to its general condition, without going into details.

As the work of the signal department grows and interlocking plants become more complex, it is very necessary not only that the organization of the repair force be highly perfected, but that the method of inspection be so systematized that no accident can be laid to the negligence of the signal repair men. To reduce inspections to a system, they should (1) be made by responsible men definitely charged with this duty; (2) be made at stated intervals, depending on the construction of a plant; (3) be made according to definite requirements which cover the essential conditions for safe working; and (4) written reports should be made by inspectors, giving the exact condition of the plant under each of the stipulated requirements.

With such a system, the third condition, or the one concerning the requirements for safe working, is the only one that calls for serious discussion. It is one that signal engineers should look into thoroughly and be prepared to give an opinion on. In the opinion of the writer, an interlocking plant can be considered safe only when an inspection shows all the parts to meet the following requirements, which are given in the form of instructions issued to inspectors:

1. Examine all switch and lock movements and see that the movement is adjusted to make full locking travel, and requires lever in machine to spring connections slightly before it can be latched.
2. Facing point lock plungers must clear lock rod ½-in. when withdrawn and have stroke of at least 7 ins.
3. See that switch points and derails are adjusted to come up tight against stock rail.
4. Lock rods to be adjusted to prevent plungers entering hole when a 3-16-in. rod or 20d. wire nail is placed between point and stock rail and 6 ins. from end of point.
5. Examine all bolt locks and see that they are properly connected and slot in switch bar is of proper length.
6. Measure hight detector bar comes above top of rail when placed at center. Any bar not coming to ¾-in. or more above top of rail at all points must be raised.

In addition to the above, inspectors are required to report on the following requirements:

7. See that all distant signals are properly adjusted.
8. State if plant is in need of oiling, finding out when it was done last and say if oiled by you.
9. State if plant is in need of cleaning, also general condition of tower.
10. Check up tool list and say if tools are kept in good order or are allowed to lie around.

Accompanying the letter of instructions the following circular was sent to each inspector:

You are to arrange to make inspection once each month of each interlocking in your charge, following carefully the instructions here given and making full report of condition of plant in regard to these at the time you leave it. Should the inspection show that repairs of any kind are needed, you will say what these are and what material will be needed to put the plant in good condition.

With inspections and reports carefullly made, as required by the instructions, the signal engineer has positive proof at hand of the condition of each important part of the apparatus at the time the inspection was made, and in case of accident would have something to show his superior officers, and, if necessary, to a jury, in support of his claim that the apparatus was not at fault.

*Abstract of a paper presented at the meeting of the Railway Signaling Club in Chicago, April 25.

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RULES FOR RAILWAY LOCATION AND CONSTRUCTION NORTHERN PACIFIC RY.

(Concluded from page 255.)

Track and Ballast.

Preparation of Roadbed.—The standard width of single track roadbed at sub-grade is 14 ft. on embankments, 20 ft. in earth cuts, and 16 ft. in rock cuts unless otherwise ordered.

All narrow banks must be widened to the standard width from centers, as established by the engineer.

Transition surves wil be used at the end of all curves of 3° and upwards. The rate of change per degree of curvature should preferably not exceed 1° for each chord of 50 ft. in length, except on mountain grades, where the chord may be reduced to the minimum length of 25 ft., when necessary.

Short sags should be avoided, and in all cases vertical curves should be provided at grade intersections, for which the engineer will establish line and grade wherever required.

The roadbed at sub-grade should be crowned to facilitate drainage by raising the center 4 to 6 ins. higher than the sides, making due allowance for ballast in establishing final grade elevation.

Ditches in cuts should be taken out in accordance with the standard cross section as follows: In earth, 3 ft., wide at sub-grade, 1 ft. deep, with side slopes 1 to 1. In rock 1 ft. wide at sub-grade, 1 ft. deep, vertical sides.

Material used for ballasting, widening banks or raising sags should be procured at points where the removal of same will benefit the roadbed by widening cuts, reducing grades or ditching. Engineers will give this subject their special attention.

Ties.—The number of ties per rail will necessarily vary with the width of the ties furnished, and will usually be from 15 to 17 ties per rail length. The minimum width between ties must not be less than 10 ins. On construction, ties will be laid 2 ft. c. to c., or 2,640 ties to the mile.

The best ties will be selected for use at joints, with faces not less than 8 ins. nor more than 10 ins. wide, and must be so placed that the outside bolt will come about the center of ties; the maximum spacing between ties at joints must not exceed 10 ins.

"Rail cut" ties must be adzed to uniform bearing, old spike holes plugged, and joint ties properly spaced for suspended joints, after the new rails are laid, and before the ballast is distributed.

In order to maintain the standard gage, three lines of spikes must be drawn if old steel rails are replaced by rails of wider section.

Distributing Rails.—The rails may be distributed either from the end or sides of train. If distributed from the sides, both ends of rail must be dropped simultaneously. Skids will invariably be used whenever necessary to unload into piles. In all cases the greatest care must be used to avoid injury to rails by dropping them on hard substances or uneven surfaces.

Curving.—Rails in curves of over 2° must be separately curved, and before being placed in track. An Emerson rail bender or bender of similar type will invariably be used for this purpose. The sledging of rails is positively prohibited.

Particular care must be given to insure uniform curvature of the rail throughout its length, in accordance with the following table of middle ordinates:

Degs.	Ins.	Degs.	Ins.	Degs.	Ins.	Degs.	Ins.
1	1/4	6	1 7/16	11	2 9/16	16	3 3/4
2	1/2	7	1 5/8	12	2 13/16	17	4
3	11/16	8	1 7/8	13	3 1/16	18	4 1/4
4	15/16	9	2 1/8	14	3 5/16	19	4 1/2
5	1 3/16	10	2 3/8	15	3 1/2	20	4 9/16

Note.—Ordinate at quarters equals three-quarters of middle ordinates.

Placing Rails in Track.—The rails must be laid to line and gage, and placed in track consecutively, throwing out both rails from the old track ahead, as the new rails are laid when track is relaid. Split points will be used for closing track for passage of trains. Accurate expansion cannot be secured if long stretches of rails are fastened up to one side of track and subsequently thrown into line, and this method is prohibited.

The track will be laid with even joints on tangents and broken joints on curves, except on sections of frequent curvature and short tangents less than 1,000 ft. in length, where broken joints will be maintained throughout.

To pass from even joints on tangents to broken joints on curves, cut and use a rail according to the following rule:

Cut rail at point distant from center of rail one-half inch for each degree of central angle of curve, using short rail on inner side of curve. For consecutive curves with short intervening tangents, obtain the separate sums of right and left central angles, subtract the lesser from the greater, and the difference will be the required angle. Use short rail on inner side of this angle. The length of the short rail must not be less than 10 ft.

"Short rails" may be used in inside line of rails in curves of large central angle, in order to maintain position of joints near center of outer rail, and in such cases the above rule must be modified correspondingly. Notes for length of cut or short rails will be furnished in advance by the engineer.

Track centers will be furnished by the engineer every 200 ft. on tangents, every 50 ft. on curves, and every 25 ft. on easement curves. The track must be laid to conform accurately to the line established.

To insure perfect alinement at rail ends, the rails should be brought squarely together, the splices placed, and carefully bolted before spiking. Perfect alinement at rail ends is of great importance in order to prevent excessive flange wear.

The position of the brand on the rail is immaterial, whether right or left, inside or outside, but its position must be uniform with the contiguous rails, and the brand should not be alternated on the same line of rails.

When relaying track, a convenient method of unloading rails from end of car is by means of two 30-ft. lines, equipped with grab hooks on each end, one end to be made fast to joints and the other end to slots in ends of rails, using the engine for moving the cars. This insures proper spacing, and is more economical than unloading from the sides. Use roller at end of car when drawing off rail.

Expansion.—Proper allowance must be made for expansion, according to temperature, as follows:

Temp.	Ins.	Temp.	Ins.
100°	0	40	9/16
80°	1/16	20	1/4
60°	1/8	0	7/16

Proper expansion must be secured by the use of iron shims, provided in accordance with the above specifications, except where track is laid on a steep grade, when sawed wooden shims of proper thickness will be provided. These shims must be left in place until track is full spiked, bolted and thoroughly anchored.

In order to prevent rails from "creeping," it is absolutely essential that each individual rail shall be so thoroughly anchored as to insure freedom from contact with adjoining rails. Creeping cannot be prevented if a number of consecutive rails are in contact.

Bolting.—The Harvey grip, or other approved form of bolt, should be used. At the time the rail is laid, two bolts should be placed in each splice, and tightened sufficiently to hold rails in line. The remaining bolts should then be placed and tightened as soon as possible. Nuts should be tightened a second or third time within 30 days after track is laid.

Inspect the rails before angle bars are tightened, and take out kinks or bends by the rail bender. The nuts must be screwed up firmly before joints are spiked.

Gaging.—The standard gage will be as follows:

On tangents	4 ft.	8½ ins.
On curves of 1, 2 and 3°	4 "	8⅝ "
On curves of 4, 5 and 6°	4 "	8¾ "
On curves of 7, 8 and 9°	4 "	8⅞ "
On curves of 10, 11 and 12°	4 "	9 "
On curves of 13, 14 and 15°	4 "	9⅛ "

The extra width of gage on curves should be uniformly decreased or tapered off, on the easement curve, from point of full curve to point of tangent.

Joints and centers should be gaged first, and the track gage must be applied at as many points as may be necessary to insure perfect and uniform gage.

Easement curves must be spiked to gage at five different points within each rail length, and all track must be accurately gaged when spiked.

Suitable track gages for use on tangents and curves, which will insure the retention of the proper gage during the operation of spiking, must be used. All track gages must be tested by the engineer or roadmaster at the beginning of the working season, and the date of inspection recorded.

Spiking.—Track must be full spiked, with inside and outside spikes driven in opposite sides of the tie. Spikes must be set half their own width from edge of rail and driven vertically to a full bearing on foot of rail. The prevalent practices of driving sloping spikes, or of giving them a final lateral blow to close the spikes against the rail, will not be permitted. So far as possible the spikes will be driven in the best wood in the tie, which is usually at the outer edge, and must not be redriven in old holes.

Elevation.—The elevation (in inches) of outer rail upon curves will be made in accordance with the following table:

Table of Elevation of Outer Rails on Curves.

Degree of curve	Rate of speed in miles per hour. 15.	20.	25.	30.	35.	40.	45.	50.	60.
	Superelevation								
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1	1/4	1/4	7/16	9/16	13/16	1 1/16	1 5/16	1 5/8	2 3/8
2	5/16	1/2	13/16	1 1/16	1 5/8	2 1/8	2 11/16	3 3/16	4 3/4
3	7/16	11/16	1 1/4	1 5/8	2 7/16	3 1/4	4	4 13/16	7 1/16
4	9/16	1 1/16	1 5/8	2 1/8	3 1/4	4 7/16	5 5/16	6 3/8	.....
5	3/4	1 5/16	2 1/16	3	4	5 1/4	6 11/16	.....	.....
6	7/8	1 5/8	2 1/16	3 9/16	4 13/16	6 3/8	.....	.....	.....
7	1 1/16	1 15/16	2 5/8	4 1/4	5 5/8	.....	.....	.....	.....
8	1 3/16	2 1/4	3 5/16	4 13/16	6 1/2	.....	.....	.....	.....
9	1 5/16	2 3/8	3 11/16	5 3/16	.....	.....	.....	.....	.....
10	1 1/2	2 5/8	4 1/8	5 13/16	.....	.....	.....	.....	.....
12	1 3/4	3 1/4	4 13/16	7 1/8	.....	.....	.....	.....	.....
15	2 5/16	3 13/16	6 1/16	.....	.....	.....	.....	.....	.....
18	2 3/4	4 11/16	.....	.....	.....	.....	.....	.....	.....
20	2 15/16	5 1/4	.....	.....	.....	.....	.....	.....	.....

The greatest elevation must not exceed 6 ins., unless otherwise directed.

The elevation of outer rail on curves must necessarily be adapted to speed and other local conditions, with due regard to safety, comfort and economy of track maintenance, for all classes of trains.

The elevation on mountain grades should not exceed that required for 25 miles per hour.

The elevation of outer rail must not be continued beyond the tangent point, but should decrease uniformly along the easement curve from point of maximum curvature to tangent point.

To ascertain the elevation required at points on easement curves, trackmen are required to use a cord of standard length, the middle ordinate of which will be equal to the proper elevation, as follows:

Speed.	Length of cord.	Speed.	Length of cord.
20 miles per hour,	31.74 ft.	40 miles per hour,	63.48 ft.
25 " "	39.68 "	45 " "	71.42 "
30 " "	47.61 "	60 " "	79.35 "
35 " "	55.55 "		

This method is applicable to all curves, and aids in maintaining true alinement, as all ordinates should be equal on full centered portions of curve, and ordinates must decrease uniformly on easement curves from full elevation to zero at tangent point. In using the cord to ascertain elevation, it should be stretched and firmly held at both ends against the inner face of rail on inside of curve. The middle ordinate will then be equal to the required elevation, and can be measured by a foot rule, or by attaching a short piece of graduated tape to the cord at its center.

All track levels must be tested by the engineer or roadmaster at the beginning of the working season, and the date of inspection recorded. Sluggish bubble tubes should be replaced.

Tie-Plates.—The standard form of tie-plate will be used, with the standard 72-lb. rail section, in lieu of rail braces.

Tie-plates will be used whenever necessary to prevent tie cutting, generally on curves of 3° or over, depending upon local conditions. The widest margin must invariably be placed on the outer side of rail.

On tangents and light curves, but two spikes will be used in each plate. On sharper curves, three or four spikes will be used, when necessary. In cases of unusual difficulty in maintaining gage on mountain grades and sharp curves, before applying tie-plates the ties may be dapped to allow a sufficient inclination to the rails to check any tendency of the rails to overturn, or to spread, observing due care to maintain gage.

In laying these plates, the line side of the tie is marked, and the plate put on, the other plate being then put on in its proper position by gaging it from the line plate with a gage rod, having lugs to fit the spike holes. The plates may be forced into the tie by a hydraulic press, or in the track by striking vertically with a paver's rammer, or with a short section of rail provided with cross bar handles. In putting plates on before the rails are laid, a wooden or metal block should be placed on the plate to distribute the blow. If put on after rails are laid, the rail may be lifted, the plate slipped in, an iron plate placed upon each projecting end of the plate, and these two plates struck simultaneously by two strikers with spike mauls, or, one end of the plate may be settled into the tie, and the free end then driven with a sledge, causing the flanges to plow their way through the wood under the rail.

Rail Braces.—Rail braces will be used when necessary with rail sections for which tie-plates are not provided, generally on curves of 4° and upwards. On curves of less degree, double spiking will usually be sufficient. The braces should always be placed in pairs on the opposite ends of the same tie.

Frogs and Switches.—Switches must be put in track in accordance with the standard plans. When temporary sidings are put in, the main line rails must not be cut, but short closure rails must be provided to fill the space between frog and the adjacent rail. Double spiked short rails should be used for this purpose.

Ballasting.—All spikes should be driven down before ballast is distributed. Ballast should not be distributed until roadbed is of full width and all unsuitable material removed. When material is unfit for use as ballast, it should be cleaned out from bottom of tie and used for widening the banks. Where there is trouble in heaving, or wet spots, the material should be taken out to such depth and in such a manner as to insure perfect drainage. Care must be taken to avoid wasting ballast down the sides of slopes, or otherwise.

The depth of ballast will be determined in accordance with the local conditions, and the character and amount of ballast already in place, if any. In general, not less than 8 ins. of good material will be required under ties.

Tamping.—Tamp the entire length of ties on new track. Special pains should be taken to insure thorough tamping from end of tie to 1 ft. inside of rail. On old track the center should be filled and lightly tamped.

Tamp joint and second ties thoroughly. Thorough tamping of the second tie from joints is of equal importance with that required by the joint ties, and will prevent the formation of cracks starting from upper edge of splices by reducing the upward deflection of joints when a wheel is over the second tie.

Material for filling and ballasting must not be taken from slopes of embankments. When ballasting is completed, the track must be in perfect line, surface and gage, in accordance with the stakes furnished by the engineer.

Ballast Cross-Section.—Rock ballast should be filled in level with top of tie from center to 2 ft. outside of rail, slopes 1 to 1.

Gravel ballast must be finished to the standard cross-section, which is as follows:

At the center and for 1 ft. on each side thereof, the top of ballast will be even with the top of ties, and thence carried out with a straight uniform slope, passing 4 ins. above bottom of ties at ends, to a point 2½ ft. outside of rail, thence to an intersection with the roadbed, with slopes of 1½ to 1.

If material is used which is more or less impervious to water, the slopes should be carried to an intersection with roadbed on a line with bottom of ties at ends.

The practice of crowning the ballast above top of tie at center causes dusty track and rots the tie at the center, and is not permitted, except when absolutely required for drainage on account of the character of material used for ballasting.

Supervision.—The engineer will furnish all necessary elevations, stakes and notes, and will make frequent inspections during the progress of track laying, in order to insure compliance with the specifications, promptly reporting defects to the roadmasters and superintendents.

Bridges and Culverts.

Inspection.—The division engineers will make occasional examinations of the condition of all important bridges and culverts. In an emergency they will, on their own authority, report such repairs as they may deem necessary for safety, to the division superintendent for immediate attention. In other cases they will make their reports to the chief engineer, who will decide on the amount and character of the work to be done.

Great care must be taken by division engineers and supervisors of bridges and buildings, to whom the security of sturctures is intrusted, to make such inspections so thorough and the records thereof so complete as to convey definite and precise knowledge of the condition of each and every structure at the time of the last inspection.

There will be two regular inspections each year, as follows:

1. In January, by the supervisor of bridges for each division, of all truss and large trestle bridges.

2. In September, by the division engineers and supervisors of bridges, of all bridges, culverts, waterways, etc.

In addition the supervisors of bridges must at all times make such other inspections as may be necessary to insure safety.

The September inspection must be made with special reference to obtaining information for estimating the cost of renewals and repairs, and for the material required for the ensuing year.

The supervisors of bridges will forward the report of these inspections, with an impression copy of the same, to the division superintendent for approval. Division superintendents will forward both copies to the division engineer.

The supervisor of bridges will make such further inspections as he finds necessary to keep thoroughly posted as to the conditions and safety of all bridges and culverts on his division.

Division superintendents will arrange to obtain the record of extreme high water at the time of each flood, or extraordinary freshet, at all bridges, culverts and openings.

Section foremen should be instructed to go over their sections at such times and take the measurement from top of tie to the extreme high-water mark, and report such measurements, giving the number of the bridge or opening, to the division superintendent.

Division superintendents will forward this information to the division engineers, who will retain copy and forward the information to the office of the chief engineer for record.

Supervisors of bridges will furnish the division superintendent monthly reports of all repairs and renewals of bridges and culverts executed during the month. These reports will be forwarded to the division engineer, who will check same against the inspection requirements, for the purpose of insuring compliance with such requirements.

At the completion of the work, the supervisors of bridges will forward a report to the division superintendent, showing all changes in the class of structure, details of construction and length, height and position of structures; also the cost of labor and material expended. This report will be forwarded to the division engineer, who, after recording same, will send it to the chief engineer for final record.

Following the September inspection, estimates of the cost of repairs, renewals and replacements recommended for the ensuing year will be prepared by the division supervisors and division engineers, which will be tabulated and forwarded through the office of the chief engineer.

The character and extent of renewals and improvements will be determined from this report. Descriptions and estimates will be given for permanent structures, wherever same appear desirable or economical.

This report will show the cost of necessary repairs recommended for the ensuing year; the average annual cost of such repairs; the total cost of the structure upon which repairs are recommended, and also the total cost and annual interest upon permanent structures when such structures are recommended.

All changes, additions or expensive renewals of bridges, culverts or other important structures, shall be made only upon the properly approved plans and estimates of the chief engineer, who will make contracts for and superintend the work.

Instructions to Inspectors.—Note books of inspection must be filled out at the structure after a careful examination has been made of each of the points itemized in the blanks, using, in cases where there are a number of spans in which defects are observed, a properly noted column for each span. When the spans are all in good condition, one column only need be used, but the number of spans should be noted.

Designate the separate spans of a bridge by numbering them in the direction of the bridge numbers on the division, and the separate bents or piers in same manner, commencing with abutment, bank-bent or sill as number one. Designate the truss as the right or left, locating points on it by numbering the panels in the same direction as the spans are numbered.

When wooden structures are four years old, such members as by their position are particularly liable to decay must be tested by boring, the holes to be plugged up as soon as the inspection is completed.

When making the regular inspections the inspectors will take a statement of the results of the last examination relative to such structures as required attention at that time, and in reporting on these structures, special notes must be made as to whether the repairs and recommendations of the previous examinations have been fully carried out or not, and whether the work is in accordance with the standard plans.

Instructions Regarding Inspection Reports.—(Numbers and directions in these instructions correspond with numbers and abbreviations on report blanks.)

1. Does waterway require straightening, cleaning out or enlarging above or below structure? Does structure afford ample waterway? Is riprap needed to maintain channel or protect roadway?

2. Note line and surface, also condition of rails, joints and fastenings on bridge and approaches. See that rails are braced on curves where necessary, and that track on approaches is firmly bedded, avoiding shock or jolt to train as it passes on to bridge.

3. Note any rotten, split or otherwise defective bridge ties, giving number, size and kind.

4. See if guard rails are in line and bolted or spiked down tight.

5. Note condition of caps and stringers, particularly at points where they bear against other members.

6. Note if plumb and batter posts are crooked, split or decayed, and if bents stand plumb.

7. See if trestle towers or bents are properly sway-braced, and all braces longitudinal and transverse are drawn up tight and have sufficient bolts or spikes to hold them properly.

8. Note particularly the condition of piles where they enter the ground or water. See that they stand properly.

9. Examine each pier and abutment as to joints, settlement, imperfect stones, cracks or other defects; note if work needs pointing up, or if cracks have opened since last pointed; make such measurements as will locate position of cracks, and note on sketch on back of report blank: Condition of riprap, if any. Is riprap needed to prevent undermining? How much? Condition of pedestal stones, and whether bridge seat is clean and water drained off.

10. Note condition of culvert and retaining walls. See if they are yielding by settlement or bulging from the pressure of the embankment.

11. Condition of ring, or covering stone, of box or arch culverts.

12. Note condition of paving and riprap, and that same is so placed that it cannot be undermined by washing.

13. Does pipe drain need head or tail wall to protect embankment from washing? And does it clear itself of water?

14. Does timber box need to be replaced with masonry or culvert pipe? If so, give dimensions required to give ample waterway, and give height from bottom of stream to rail.

15. See if bed plates and rollers are clean, and if the

latter stand so as to move squarely back and forth with the truss. See if pedestal takes an even bearing on rollers. Examine anchor bolts.

16. Observe particularly the condition of wall plates where bolster rests upon them. Note any appearance of crushing or decay.

17. Note condition of bolsters and corbels. See if holes are bored through them where they cover the spaces between chord sticks, to prevent the collection of water, and if there is any indication of decay where they are in contact with chord.

18. Angle blocks and all cast-iron members such as chord boxes, post shoes, etc., must be examined for cracks and for any indication of displacement by reason of daps splitting or timber crushing. A hole of ¼-in. in diameter, if drilled at the end of a crack, will frequently stop its extending farther.

19. Note particularly any appearance of opening of bottom chord joints. Wooden bridges over four years old should have gage blocks at all joints in the middle half of the span, made by fastening two planed and squared blocks 1 × 2 ins., 6 ins. long, to the chord sticks with screws, and scribing a fine line across both. Any movement of joints should be noted, giving location and amount, scribing a new line from the old one on the outside block across the inside block. See if clamp daps are shearing.

20. See that all chord and packing bolts are tight. Nuts on all bolts through guard rails, ties, stringers and floor beams must be secured in place by burring the thread of the bolt at two or three places with a center punch or cape chisel.

21. Note any signs of decay or crushing in packing blocks, and see that clamps and keys are in proper condition.

22. See if gib plates are distorted, or crushing into the chords; if they are, give their location and dimensions, number, size and spacing of rods passing through them. Give size of rods over threads.

23. Note condition of sides and roof of covered bridges, or of chord and end post covering.

24. Notice particularly the connections between stringers and floor beams; see that connecting angles are not split, either in the angle or through in the line of the rivet holes. For wooden stringers, note condition as to soundness and bearings.

25. Notice particularly the connections between floor beams and trusses for evidence of imperfect bearing, or splitting of connecting angles. If suspended, notice if they are up tight against the post feet, or free to move.

26. Test equality of tension in tie bars by springing them. Look for any signs of distortion or crookedness in bars of end panels of bottom chords. Howe truss rods, counter lateral and vibration rods must never be allowed to hang loose. They must not be adjusted while a load is on the bridge. They should be tightened enough to give close and even bearings, but must not be overstrained, as unnecessary strains are put on compression members if too much power is used in adjusting tension members. See that the center line of all tension members is the same as the line of strain.

27. Examine carefully, especially at the joints.

28. See if posts, lateral struts and top chords are straight and free from twists. On wooden bridges, see if braces are up in place, taking a square bearing at ends, and note if any warping is evident. Note their condition as to soundness.

29. Examine all lateral connections, and see that lateral tension members are straight. Examine bracing in iron trestles.

30. Make particular examination of all hangers, testing each nut to see that it is tight. A streak of white paint drawn across nut and bearing will indicate any movement. These nuts should be screwed up tight and secured by burring the thread of bolt and nut at two or three points with a center punch or cape chisel.

31. Note any pins which indicate the movement of any of the members coupling on them, or that have loose nuts. All pins and nuts should have a streak of white paint across nut and pin end.

32. All field driven rivets in floor beams and stringer connections should be lightly sounded to see that they are tight. Also lateral connection rivets in riveted trusses, and any intersection or other rivets which indicate by rust streaks, or otherwise, that there is movement at that point.

33. Note if there are any members, such as closed columns, pedestals, etc., which catch and retain water by reason of not having proper drain holes.

34. Note carefully the line of each truss by the top chord and by points on the floor beams equidistant from the center of the posts. Also note the camber by the top and bottom chords, whether it is true and uniform or irregular.

35. Look for loose rods, hangers, loose braces, unequal sized timbers and other defects which require adjusting in order that each of the different parts may have proper bearings and carry its proper part of the load.

36. Note any undue vibration of the structure under live load.

37. Note excessive deflection of the structure under live load, seeing if the two trusses have the same deflection.

38. See if any rust spots are apparent under the paint. Note if structure needs repainting. Iron bridge work should be scraped and repainted as often as necessary to preserve from rusting.

39. Note such wooden structures as require barrels to add to their safety, giving number required. State condition of such barrels as may be in position. On all bridges of such magnitude as to require a watchman, there should be a foot plank between the rails securely fastened to the ties to facilitate crossing the bridge quickly in emergencies, such as fire or danger to trains. Note if ladders, either fixed or portable, are required for the safety of the structure or to facilitate inspection.

40. See if material, driftwood, weeds, grass or other rubbish is properly removed and burned, or otherwise disposed of.

List of Abbrevations for Class of Structures.

W. B.—Wooden or timber box culvert.	P. B.—Pile bridge.
	P. C.—Pile culvert.
S. B.—Stone box culvert.	T. B.—Trestle bridge.
S. A.—Stone arch culvert.	H. T.—Howe truss.
T. P.—Tile culvert pipe.	C. T.—Combination truss.
C. P.—Cast culvert pipe.	I .T.—Iron truss.
B. D.—Blind drain.	D. S.—Draw span.
W. C.—Wall culvert.	P. G.—Plate girder.

Erection of Steel Bridges.

General.—Engineers, inspectors and contractors are expected to make themselves thoroughly familiar with the general and special specifications governing the work.

All material received must be carefully checked, recorded and reported immediately upon receipt of same, in accordance with the rules. Shortages should be reported immediately. Material received should be checked against complete bill of material, and every effort made to avoid delay to the progress of the work, by failure to receive material, including false work, tools, etc., etc.

The engineer in charge must cause to be kept an accurate record of the cost of the work, including material and labor, keeping separately each class of work, such as rigging up, unloading, repairing, raising, fitting, riveting, cleaning, painting, framing, bolting, contractors' pay roll, character of plant, framing and erecting false work, and removal of same. A diary must be kept containing dates of commencing and completing different classes of work, and all other general information of value. A record, or copies of all orders, on instructions, issued or received during the progress of the work, and the daily force account should also be kept.

The engineer in charge must check all distances and elevations on plans, before laying out the work, and will be held responsible for any errors that may arise, through neglect on the part of himself or assistants, properly to verify and recheck, plans, points and elevations, given for the erection of the structure. Distances between centers and elevations of finished tops of masonry are especially important, and should be rechecked as often as may be necessary, in order absolutely to insure against errors. The sum of the heights of the component parts forming the structure should be carefully checked against the total finished height, above assumed datum, to base of rail. The sum of all detail lengths must also be checked, with equal care, against the total length from the fixed initial point.

Insure that the material shall not be injured, nor dangerously strained during the operation of loading, unloading or handling same. All defects in workmanship or material must be remedied as soon as detected. A thorough inspection must be made for defects in painting, cleaning, reaming, spots of shrivelled oil or paint, chips, burrs, sharp edges and black or rusty spots on steel, scale, cinders and scratches, particularly in joints and around rivet heads, brush hairs, or other foreign matter covered over with paint or oil; all such defects shall be remedied immediately, and noted in detail, to provide full information, in case of claims for extra compensation.

Slight bends in members shall not be straightened unless strictly necessary, on account of the danger of overstraining connections and rivets. Connection plates, if slightly bent or twisted, shall be straightened cold; if bent so sharply as to require heating, the whole piece thus heated shall be subsequently annealed. All shop rivets, or any piece of member thus straightened, shall be properly tested.

Particular care will be taken to insure free expansion and contraction, wherever provided for in plans. Any departure in dimensions, amount of camber or otherwise, of material received, from plans and specifications, must be noted and reported immediately.

All machine-fitted bolts shall be perfectly tight, and should be burred or otherwise checked to prevent nuts from becoming loose, and no unfilled rivet or bolt holes should be left in any part of the structure.

Fitting and Chipping.—The material must be assembled in accordance with the match marks, and no interchange of pieces must be made, unless absolutely necessary in order to avoid chipping and fitting, or serious delay.

Fitting and riveting of connections (especially angles) in cases where pieces are short or full, must be done in such a manner that the metal is not unduly strained, or cracks caused.

Dishonest or incompetent workmen frequently fill cracks with paint, putty, cinders, dirt, oil or filings, for the purpose of deception. A close inspection must be made for this.

Wooden rams or mails must be used in forcing members to position, in order to protect metal from injury or shocks.

Chipping of rivets, angle flanges, and edges of plates, must be done without breaking out metal. Chipped edges must be finished off with a file, and all concave corners must be rounded off. Chipping with a sledge will only be permitted in exceptional cases, and must be done without leaving fractured edges.

Riveting.—In driving rivets, the dolly and die should be placed directly opposite each other, at right angles to the riveted surface, to insure straight driving. Rivets must be driven while at an orange heat, and no burnt rivets should be used.

After riveting, each rivet must be tapped with a hammer to insure that they are tight, and the heads must be well formed, concentric with center of rivet, and closely fitted against the riveted surface.

Defective rivets can usually be detected by their color, or by sound when tapped with a hammer, and all loose or burnt rivets must be immediately cut out and replaced.

In cutting out rivets be careful to ascertain that other rivets in proximity have not been loosened.

Tightening up, recupping or calking old rivets will not be tolerated, except that occasional recupping of shop rivets do not form part of important connections, or do not directly transmit stresses.

Countersunk rivets must be inspected after chipping heads, and no unnecessary chipping should be permitted.

Painting.—The specifications under the head of cleaning, oiling and painting must be strictly carried out.

An accurate account should be kept of the quantities and proportions used, of pigments, oils and other ingredients, and the quantities by weight or fluid measure, of the resulting mixtures, ascertained. A record should be kept of the quantity of paint applied, of each coat, and its proportion ascertained to area or weight of material covered.

Paint should be thoroughly worked in all corners and joints, and narrow openings, covering edges and sealing up all lines of contact between parts.

Unless otherwise specified, the ingredients and proportions of the mixture, for the three coats, shall be as follows:

First Coat.—30 lbs. pure lead to 1 gallon pure boiled linseed oil, 1-3 pint pure turpentine.

Second Coat.—25 lbs. pure lead to 1 gallon pure boiled linseed oil, ¼ pint pure turpentine, lampblack, quantity not to exceed 12 ounces.

Third Coat.—15 lbs. dry pigment, Cleveland Ironclad, purple band No. 3, to 1 gallon of pure boiled linseed oil.

Accounting and Miscellaneous.

(Space compels us to omit the instructions under this head, covering Bills, Vouchers, Cash Expenditures, Time Returns, Pay Rolls, Time Certificates, and the distribution of expenditures to different accounts, each of which is described in detail. Instructions are also given for tracklaying reports, instrument reports, the transfer of materials to the operating department, and carrying on commercial traffic while the road is still under construction. The book closes with some useful tables of supplies, and engineering and camp equipment for field parties which we give in full.—Ed.)

Supplies for 14 men, 30 days.

400 lbs. Flour.	50 lbs. Beans.
50 lbs. Buckwheat flour.	25 lbs. Rice.
40 lbs. Oatmeal.	10 lbs. Corn starch.
30 lbs. Cornmeal.	1 box Macaroni.
150 lbs. Sugar.	10 lbs. Barley.
20 lbs. Salt.	1 box Soap.
10 lbs. Tapiaco.	1 bottle Lemon extract.
10 lbs. Sago.	1 bottle Vanilla extract.
10 lbs. Baking powder.	10 lbs. Currants.
2 lbs. Mustard.	1 box Raisins.
1 lb. Pepper, ground.	5 gallons Syrup.
½ lb. Ginger, ground.	6 bottles Pickles.
½ lb. Cinnamon, ground.	20 lbs. Onions.
¼ lb. Allspice, ground.	1 gallon Vinegar.
100 lbs. Ham.	6 bottle Tomato catsup.
100 lbs. Bacon.	1 case Corned beef.
25 lbs. Dried beef.	3 lbs. Baking soda.
25 lbs. Codfish.	50 lbs. Evaporated apples.
400 lbs. Potatoes.	50 lbs. Dried peaches.
1 case Pears.	50 lbs. Dried prunes or plums.
1 case Cherries.	¼ lb. Nutmegs.
2 cases Tomatoes.	1 box Soda crackers.
2 cases Peaches.	12 boxes Matches.
2 cases Corn.	1 box Candles.
1 case Peas.	2 lbs. Lye.
1 case Condensed milk.	10 lbs. Sal soda.
50 lbs. Coffee.	60 lbs. Butter.
10 lbs. Tea.	8 bottles Worcestershire sauce.
40 lbs. Lard.	1 case Coal oil.
12 packages Yeast cakes.	
25 lbs. Cheese.	

Eggs, fresh meat and vegetables as required, if they can be obtained from the farming community.

Engineer Equipment and Stationery (for One Feld Party).

1 Transit.	2 yards Red Flannel.
1 Level.	2 yards White flannel.
1 Chain, 10 extra links, 1 extra handle.	1 Sounding rod, 3 joints, 8 ft. each.
4 Flag poles.	6 6-H Pencils.
2 Level rods.	12 4-H Pencils.
1 Hand level.	12 No. 2 Pencils.

1 Barometer.
1 Pocket compass.
1 Clinometer.
1 Protractor, paper.
48 Thumb tacks.
6 Camel hair brushes.
1 Scale, triangular, decimal.
1 Straight edge, 36 ins., steel, nickel-plated.
1 Drafting board and trestles.
1 Stationery chest, tray and board.
2 Hand axes and extra handles.
3 to 6 axes and extra handles.
1 Hatchet.
1 Water keg, 2 gallons.
2 Brush hooks.
2 50-ft. Tapes in cases, 2 without cases.
1 Bottle mucilage.
2 Bottles india ink.
1 Stick india ink.
1 pint Combined writing fluid, stone bottle.
1 small bottle Red ink.
2 doz. Shipping tags, N. P. Ry.
2 doz. Shipping tags, N. P. Ex.
5 Transit books (form 60).
10 Level books (form 60).
10 Topography books, (C. D. 61).
6 Scratch blocks.
12 Blotters.
1 Time check book.
1 doz. Property reports (form 11).
1 block Vouchers.
12 papers Tacks, 8 oz., tinned.
3 quires Wrapping paper.
2 balls Twine.
12 Timber leads.
100 Manila envelopes, large.
100 Manila envelopes, small.
6 Colored pencils, red and blue.
12 Penholders.
1 box Assorted pens.
12 Crow quill pens.
1 Slab for india ink.
2 Inkstands.
1 Pocket inkstand.
2 Pads letter paper.
2 Pads note paper.
2 Pyramids pins.
6 Rubber erasers.
1 Steel eraser.
3 quires Foolscap.
3 quires Journal paper.
1 box McGill's paper fasteners.
50 sheets Cross-section paper, 10ths.
4 Triangles, 10, 8, 7, and 5 ins., 30° and 60°.
30 yards Drawing paper, 24 ins. wide.
1 roll Plate A profile paper, divided.
1 roll Tracing cloth, 30 ins.
1 Stylus book, with carbons.
24 Time returns (form 102)
1 Book of receipts (form 104).
1 Pad form B. A. 100.
1 Book N. P. B. A. rules and regulations.
1 Book transportation rules.
1 box Rubber bands, assorted.
2 Tin map cases, 6 x 36 ins.
2 lbs. Kell.
2 quires Legal cap.

In the case of extended explorations beyond civilization, apply to Chief Surgeon of the N. P. Beneficial Association for small supply of medicines and "first aid package" and instructions how to use them.

Camp Equipment (for one Field Party).

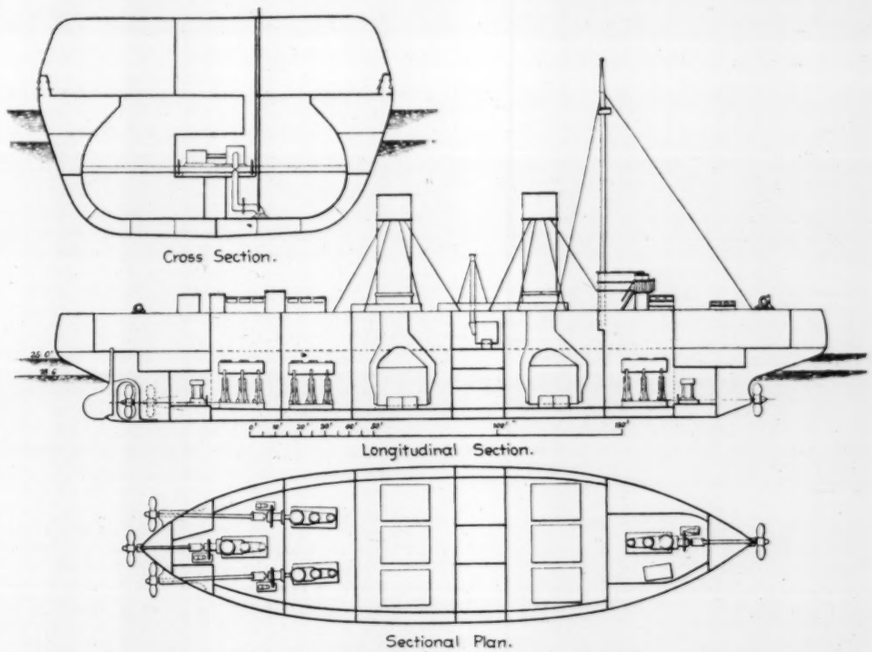
4 Tents and flies, 14 x 14 or 14 x 16.
1 Grindstone.
1 Monkey wrench.
1 Spade.
1 Hand saw.
1 Cross-cut saw.
1 Alarm clock.
1 Two-gallon keg.
1 Washtub, board and boiler.
1 bundle Sail twine and needles.
1 Sail palm.
10 yards Canvas.
2 Three-cornered files.
1 Flat file.
10 yards Toweling.
1 Scrub brush.
1 Broom.
3 Candlesticks.
3 Stand lamps and 6 chimneys.
2 Stewpans.
1 Water pail.
2 Griddles.
1 Coffee mill.
4 Drip pans, 12 x 17.
1 Five-gallon dish pan.
1 Five-gallon bread pan.
4 Large iron spoon, 12 ins
1 Soup ladle.
1 Cake turner.
1 Steel.
3 Butcher knives.
1 Chopping bowl.
1 Chopping knife.
3 Pepper boxes.
1 Sieve.
1 Steamer.
1 Colander.
2 Can openers.
1 Meat saw.
1 Potato masher.
1 Rolling pin.
1 Nutmeg grater.
1 Bread board.
10 yards Oil cloth.
1 Flesh fork.
1 Buscuit cutter.
36 Teaspoons.
36 Tablespoons.
36 Knives.
36 Forks.
1 Carving knife.
1 Carving fork.
1 Tea kettle.
1 Tea strainer.
24 Coffee cups.
2 Candle lanterns.
3 Washbasins.
2 Dippers.
1 Lunch basket.
1 Dinner table.
2 Trestles for tables.
1 Cook table.
2 Sibley stoves, sheet iron
1 Cook stove.
3 pieces Pipe, with dampers.
12 pieces Pipe without dampers.
2 Iron pots.
1 Three-gallon coffee pot.
1 Two-gallon tea pot.
1 Large frying pan.
1 Small frying pan.
2 No. 28 Stew kettles, galvanized iron.
24 Pint cups.
36 Plates.
1 No. 24 Stew kettles, galvanized iron.
12 Pie plates.
4 Three-quart Pans.
4 Four-quart Pans.
4 Six-quart Pans.
18 pint Pans.
3 Tin pot covers.
2 Three-gallon Galvanized water pails.
1 Two-gallon Tin water pail.
1 Pick and handle.
2 Mess chests.
5 lbs. 10d. Nails.
100 ft. ¾-in. Manila rope.

THE RUSSIAN ICE-BREAKING STEAMER "ERMACK."

In February last a peculiar steamer was completed for the Russian government, at the shipyard of W. G. Armstrong, Whitworth & Co., at Walker-on-Tyne. The general design for this vessel, which has been named the "Ermack," was made by Admiral Makaroff, of the Russian Navy, with a view to the use of the vessel to keep open communication, in the winter months, between the Baltic Sea and Cronstadt and other ports of Northern Russia. In this region the ice becomes exceedingly thick, and these ports have been ice-bound from early in November to the middle of April, so that all navigation ceased.

From articles in "Engineering" of London, for Feb. 24 and March 31, we obtain the following general notes regarding the design of this ice-breaker, and the work it has already accomplished in breaking the ice-blockade. The "Ermack," the largest and heaviest craft of its kind in the world, is 305 ft. long, 71 ft. beam and 42½ ft. deep, with 25 ft. draft when ready for work. The cross-section of the hull is especially designed to resist the crushing effect of heavy ice closing around it. The three screws at the stern are arranged to send a strong current backward from the ship to carry away the ice. These screws also serve to propel the vessel. The bow propeller is not expected to aid much in propulsion, but it aids the ship to clear her way, as the current from it tends to prevent ice accumulating under the ship's bottom. By reversing this bow-screw, the current from it is directed forward, washes out lumps of ice from beneath the field, and assists the overhanging bow to break down the ice.

The hull is remarkably strong, and is divided into 48 watertight compartments, which were tested while the ship was on the stocks by filling them with as much as 2,500 tons of water, in all, at one time. The ribs, deck beams, stringers, floors and longitudinals are connected and stiffened by brackets, gusset pieces, etc., of unusually heavy dimensions. The double bottom is carried some distance up the sides, and then curves boldly in to form coal bunkers; the larger compartments above these latter form a cargo space. As will be seen, the outer shell could be pierced without flooding the main compartments. The ice-belt plating extends from bow to stern, is 20 ft. deep, and is from 1¼ to 1 1-16-in. thick; this belt is flush-plated, with inside butt-straps.



SECTIONS OF THE RUSSIAN ICE-BREAKING STEAMER "ERMACK."
Sir W. G. Armstrong, Whitworth & Co., Elswick, England, Builders.

Each propeller has a set of triple expansion engines, for exerting full-power; and at the side of the shafting of each screw is a pair of small compound engines to drive the propeller by toothgearing. The cylinders of the main engines are 25½, 39½ and 64 ins. diameter, by 3 ft. 6 ins. stroke. The six boilers are each double-ended, 15 ft. diameter and 20 ft. 6 ins. long; the two funnels are 90 ft. high and 11 ft. 6 ins. and 10 ft. 6 ins., outside and inside diameters. The grate surface is 800 sq. ft., with a total heating surface of 27,600 sq. ft. The stern propellers are 14 ft. diameter; the two wing propellers having 14 ft. 6 ins. pitch, and the center propeller 14 ft. pitch. The bow propeller is 13 ft. diameter and 13 ft. 6 ins. pitch. All of these propellers are four-bladed, enormously thick, and made of nickel-steel, with 3% nickel. The light draft of the vessel is 19 ft., with 25 ft. draft in working order, with 3,000 tons of dead weight.

The maximum indicated horse-power is 12,000, equivalent to a maximum speed of 16¼ knots. The total capacity of the ship to the upper deck is 14,783 tons; of this 3,900 tons may be taken as coal, and cargo, if the latter is required. The pumping arrangements are very complete, including a salvage pump with a capacity of 10 tons of water per minute. The two ballast pumps are arranged to take hot water from the boilers and discharge it through valves in the bow, so that it will run down over the outside plating. This is to prevent rough ice from adhering to the sides. There are also four 12-in. centrifugal pumps, a pair of Weir pumps, and one auxiliary feed pump, in each of the three engine rooms, along with one duplex and one bilge pump in each engine room, the two ballast pumps, before mentioned, and several smaller pumps. Among other machinery there are three evaporators, of 25 tons capacity each, for providing fresh water, and a separate fresh water distilling plant for drinking purposes.

For towing another vessel through ice, a recess is built into the counter of the "Ermack" (but not shown on the plans given), in which the stem of another vessel could be securely lashed. Specially strong towing appliances are also provided.

As to actual performances "Engineering" gives the following notes: The first ice met by the "Ermack" in the Baltic was drift-ice, 5 ft. thick. She went through this with comparative ease at a 9-knot speed. She next encountered ice estimated at 25 ft. thick, and went nearly through this before she was brought up. According to accurate measurements the ice field was here 5 ft. thick, the pack on top was 9 ft., and there were about 11 ft. of crushed ice under the field and frozen to it. The worst field ice met with was 4 ft. thick, with snow on top; and this snow seemed to be the greatest impediment to the ship's progress, as was expected by the designers. It was reported that 12 ins. of snow on top of thick ice was a serious impediment, and 18 ins. almost blocked the vessel. On approaching Cronstadt the ice was 18 ft. thick in all, with considerable snow on top; but the "Ermack" steamed through this at a 6½-knot gait. She came in through an entrance 95 ft. wide, though her beam was 71 ft., and steered admirably; she then turned in a circle of about 600 ft. diameter in ice 2 to 3 ft. thick. The aid given by the bow propeller was very noticeable, and when this propeller stopped the ship stopped too, as a rule. In outside work, pieces of drift ice covering 2 to 3 acres were pushed aside easily. At Cronstadt the "Ermack" released nine ice-bound steamers, and convoyed them out to sea; and she brought others in from the outside. By all accounts, she is an eminent success as an ice-breaker.

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ADVERTISING RATES: 20 cents per line. Want notices, special rates, see page XIX. Rates for standing advertisements sent on request. Changes in standing advertisements must be received by Monday morning; new advertisements, Tuesday morning; transient advertisements by Wednesday morning.

Governor Roosevelt has added another to the long list of statesmanlike acts which the public has set down to his credit, by sending a message to the legislature opposing the proposed amendment of the New York Rapid Transit Act, empowering the Commission to grant a perpetual franchise. He said in his message:

> It does not seem to me wise that a franchise of this nature should be given in perpetuity. It would of course be best to have it owned by the municipality. But if the measure must be undertaken by a private company, then the bill should be so framed as to throw open the competition to all responsible bidders, and the franchise should not, in my opinion, be given for more than 50 years, then to be revalued by arbitrators or by the Supreme Court; the franchise to be thereafter continued for terms of 25 years unless the city desires to take the road at the valuation agreed on.
>
> What the value of this franchise may be 50 years hence no one can tell; and while, in view of the formidable difficulties of the undertaking, full provision should be made for ample reward to the private capitalists who go into the scheme, if it is deemed advisable to have it undertaken by private capital, yet the franchise should not be given in perpetuity, and provision should be made to remunerate the city if the franchise turns out to possess exceptional value.

It is generally conceded that the Governor's determined stand upon this matter has defeated the attempt to push the perpetual franchise amendment through the legislature; and has also greatly improved the prospects for municipal construction of the road. As for the Metropolitan Street Railway Co., its dictatorial insistence that its offer to construct and operate the road must be accepted or rejected in entirety, and its ostentatious withdrawal of the offer on the ground that it must have a perpetual franchise or nothing, has greatly injured it in the public estimation. It is the height of absurdity for the Metropolitan company to attempt to make people believe that a perpetual franchise would be essential in order to raise capital for the construction of the road as a private enterprise. The road will be built from the proceeds of bonds in any event, and bonds maturing in 100 years sell no higher in the market than bonds which mature in 25 to 40 years. If the city desired to reserve the right to take possession of the road at the end of 50 years, agreeing to pay at that time its cost of construction, the bondholders would be perfectly secure.

We have fully recognized, and were among the first to point out that the Metropolitan Street Railway Co. ought to operate the Rapid Transit railway in connection with its own lines, in order to secure the greatest measure of public benefit. Even if the road should be built by the city, it would probably be leased to the Metropolitan company for operation. For the company to assume an arrogant and dictatorial attitude, however, and to attempt to take advantage of the monopoly which it holds by virtue of franchises already granted to it by the city, is a most unwise policy, and is well calculated to strengthen the case of those who advocate the municipal operation of street railway lines.

We conclude in this issue our publication of the rules issued by the engineering department of the Northern Pacific Ry., reprinting in full the sections relating to the maintenance of track and ballast, the inspection of bridges and culverts, the erection of steel bridges, and the equipment for engineering field parties. The practical value and usefulness of these detailed instructions will be appreciated, we are sure, by all our readers interested in railway work. The detailed rules for the guidance of bridge inspectors are especially worthy of mention, as they represent a class of work that does not always receive proper attention. Many of our readers may remember a serious bridge disaster on a prominent New England railway some half-dozen years ago, in which it was developed by the Railway Commission's investigation that the bridge inspection of the company was largely a farce, and that this was chiefly due to the curtailment of the authority and responsibility of the engineering department. In another New England railway accident, which was investigated by the same able commission a few years ago, the interesting fact was developed that some of the car inspectors whose duty it was to sound the wheels of passenger coaches, had no idea how to detect a defective wheel, and went about their duties in the belief that the main purpose in sounding the wheels was to convince passengers that proper precautions were being taken for their safety.

It needs no argument to prove that inspection of this sort is worse than useless. It deceives by giving a false sense of security. The first step in proper inspection of any sort is to instruct the inspectors. The too common practice of letting each inspector follow his own ideas as to what is and what is not good practice, is absurd upon its face. The workmen from whom inspectors are drawn very seldom have the technical knowledge and experience to fit them to decide such questions, and it is a mistaken course to place such a responsibility upon them.

Another field in which the need of intelligent and systematic inspection is now apparent is the signal department; and in another column of this issue a well-known signal engineer submits a set of rules for the guidance of signal inspectors. The need of such rules is again illustrated by the writer's statement that most railways at present leave the methods of inspection largely to the discretion of the individual inspectors.

A number of interesting points are brought out by the report of the St. Louis Committee on the Chicago Drainage Canal, published elsewhere in this issue. Perhaps the most striking suggestion in the report is that the Sanitary District should bring itself up short before adding to its expenditure of $28,000,000 under the present plan, and put the $11,000,000 additional, which the report assumes will be required to complete the work, into another scheme. This $11,000,000, the report states, "would go far towards the construction of a better system." Just what this system would be is not specified, although it may be inferred that purification works would be a main feature.

So far as St. Louis is concerned, the present plan is considered objectionable because it continues to discharge unpurified sewage into the city's water supply. With the canal in operation, discharging 300,000 cu. ft. per min. of sewage and water, and assuming 8⅓% of this to be sewage, the minimum flow of the Mississippi River at St. Louis will be to the sewage of Chicago as 91 to 1. If all of Chicago's sewage now went to the Mississippi, which we understand is not the case, although so assumed in the report, the dilution at the minimum river stage would be as 80 to 1. Although the exact figures are not at hand, the amount of sewage sent down to St. Louis when the canal is put in operation will doubtless be considerably more than at present, but it will be far more diluted. If all the sewage of Chicago were going by St. Louis now the dilution would be about one-half, assuming 25,000 cu. ft. of sewage per min., and a total pumpage at Bridgeport of 50,000 cu. ft. per min. At best the dilution now is probably not over 2 or 3 to 1, while with the same amount of sewage, and the canal in operation, the dilution will be 11 to 1. But the report urges that the Chicago River now acts as a septic tank, and that with the canal in use, the sewage will go seaward faster, and thus a larger number of germs be carried a greater distance than at present. This is a matter for consideration, but the increased dilution with fresh lake water will very likely more than offset it.

The commission very truly says that because St. Louis has been imposed on in the past gives no excuse for a continuation of the imposition, which becomes all the more forceful when it is remembered that the drainage canal is supposed to be the substitution of a scientific for a makeshift policy. On the other hand, it is not strange that Chicago was staggered at the task of purifying its sewage. Messrs. Rudolph Hering, Samuel G. Artingstall and Benezette Williams estimated in 1887 that the purification of the sewage from a population of 2,500,000 in Chicago by land treatment would cost $54,000,000 for construction, and $3,000,000 annually for interest, pumping and maintenance, after deducting proceeds from crops. To reach suitable land the sewage would have to be lifted 90 ft. through a force main 20 miles long. The estimate for construction included intercepting sewers and pumping stations.

The St. Louis committee believes that the alleged engineering defects of the present plan are not the only objection to it. It urges that under the enabling act the opening of the canal may be blocked for years in the State courts, besides which the Sanitary District may not be able to secure Federal authority to divert water from the lakes to dilute the sewage, as called for in the act. It adds to these possibilities the fact that before the canal can be enlarged to carry 600,000 cu. ft. per min. Congress must vote to improve the Des Plaines and Illinois rivers, and assume damages to private property caused by overflows due to a discharge of more than 300,000 cu. ft. per min. Altogether it would appear that there are several possible snags ahead for Chicago.

We are glad to note that the commission recognizes the position in which its report places St. Louis in the matter of water pollution. It urges that by general laws of the United States the pollution of interstate streams must soon be stopped, and that State and municipal regulations will demand the purification of public water supplies under suspicion. It therefore recommends that "St. Louis so shape its course as to meet both of these propositions before the necessity for meeting them is forced on the city by epidemics, and drastic measures of general law."

At the recent meeting of the Institution of Naval Architects, the leading paper presented was by Rear-Admiral Geo. W. Melville, Chief Engineer, U. S. N., on "The Logical Arrangement of the Motive-Power of Warships." As our readers are aware, the United States cruisers "Columbia" and "Minneapolis" are fitted with three propellers, each propeller being driven by a separate engine. At the time of their construction, it was stated that the three screws were expected to be, on the whole, somewhat less efficient than twin screws on account of the fact that the central propeller would be working in the water discharged from the side screws; and the reason at that time assigned for the use of three screws was that the size of the engine parts, shafting, etc., would be so great if twin screws of the desired total power were used, that they could not be produced with the facilities then existing in the United States.

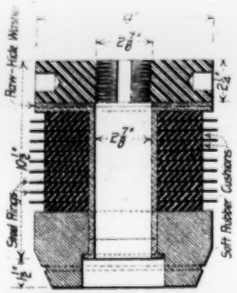


FIG. 7. BUFFER AT UPPER END OF SCREW.

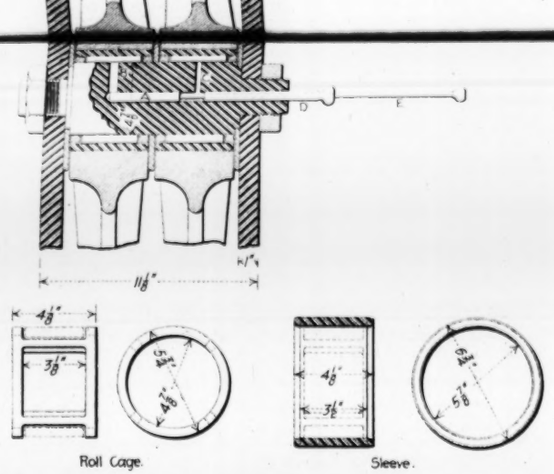


FIG. 6. DETAILS OF ROLLER BEARINGS USED IN THE MULTIPLYING SHEAVES.

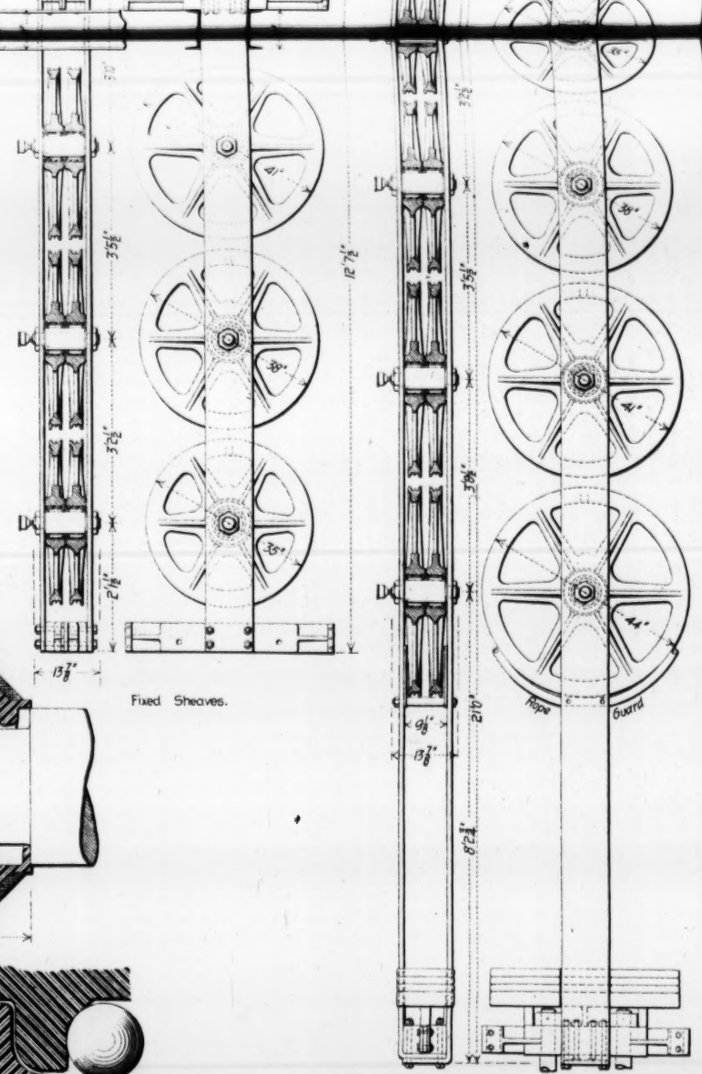


FIG. 5. DETAILS OF FIXED AND TRAVELING MULTIPLYING SHEAVES.

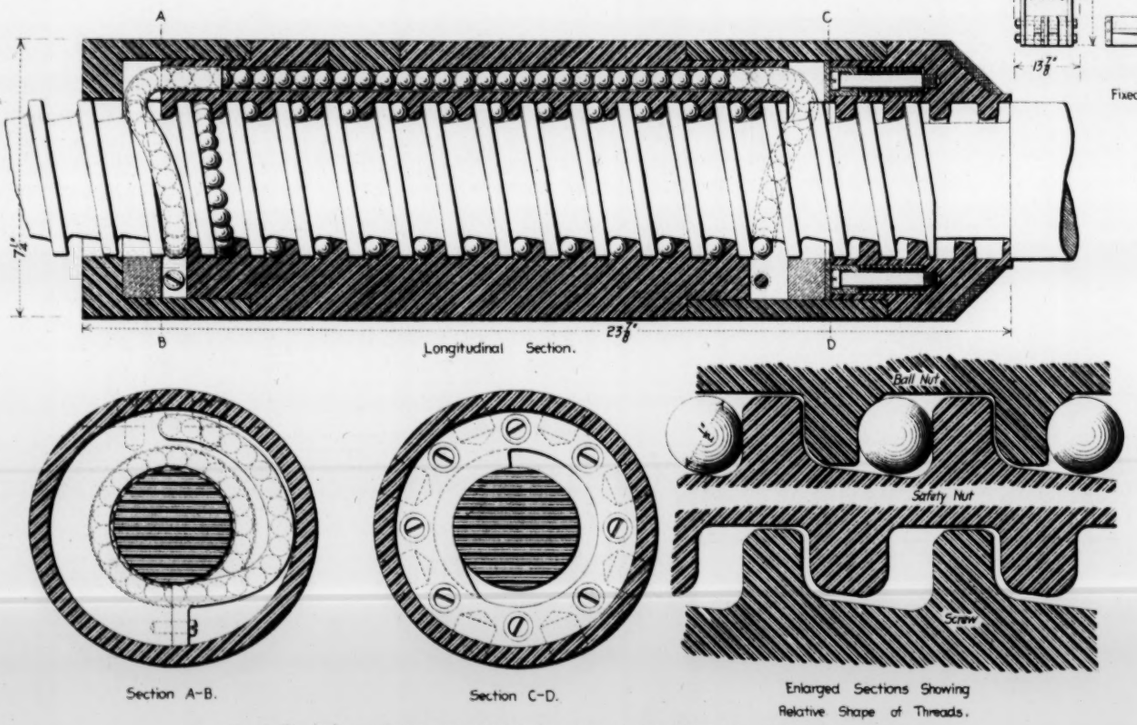


FIG. 9. DRIVING SCREW AND NUT, SHOWING METHOD OF FEEDING THE BALLS.

ELECTRIC ELEVATORS FOR THE IVINS SYNDICATE BUILDING, PARK ROW, NEW YORK CITY.

Sprague Electric Co., New York City. Frank J. Sprague, Technical Director. Charles R. Pratt, Mechanical Engineer.

CHAS. HART, LITH., 26 VESEY ST., N. Y.

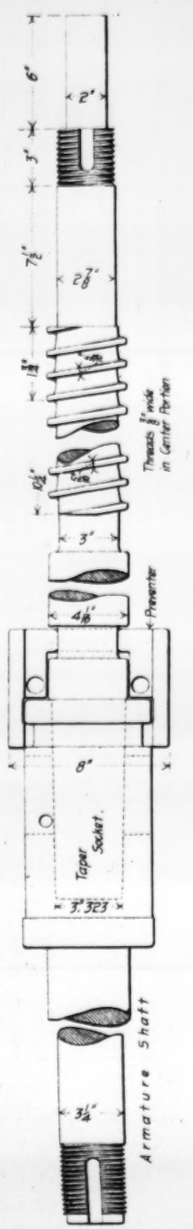


FIG. 8. END OF ARMATURE SHAFT AND DRIVING SCREW, WITH PREVENTER.

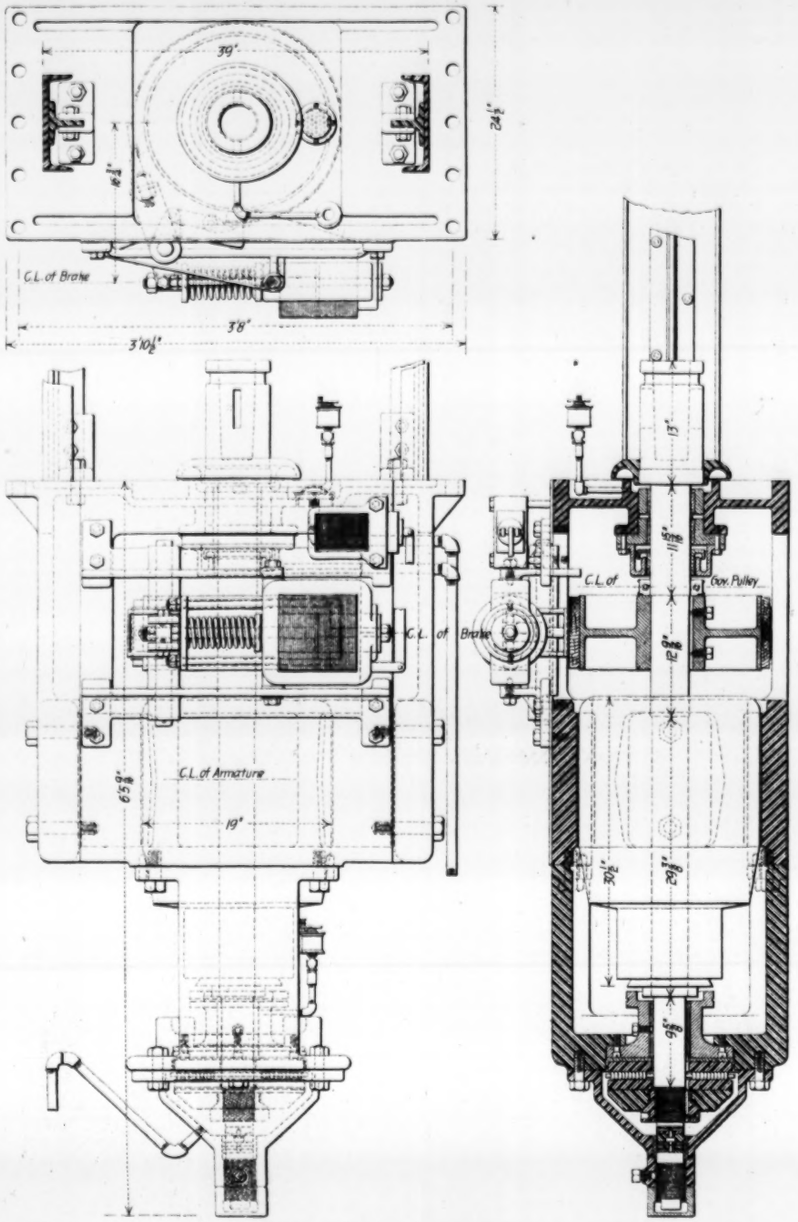


FIG. 10. PLAN AND ELEVATIONS OF MOTOR, SHOWING DETAILS OF THRUST BEARINGS.

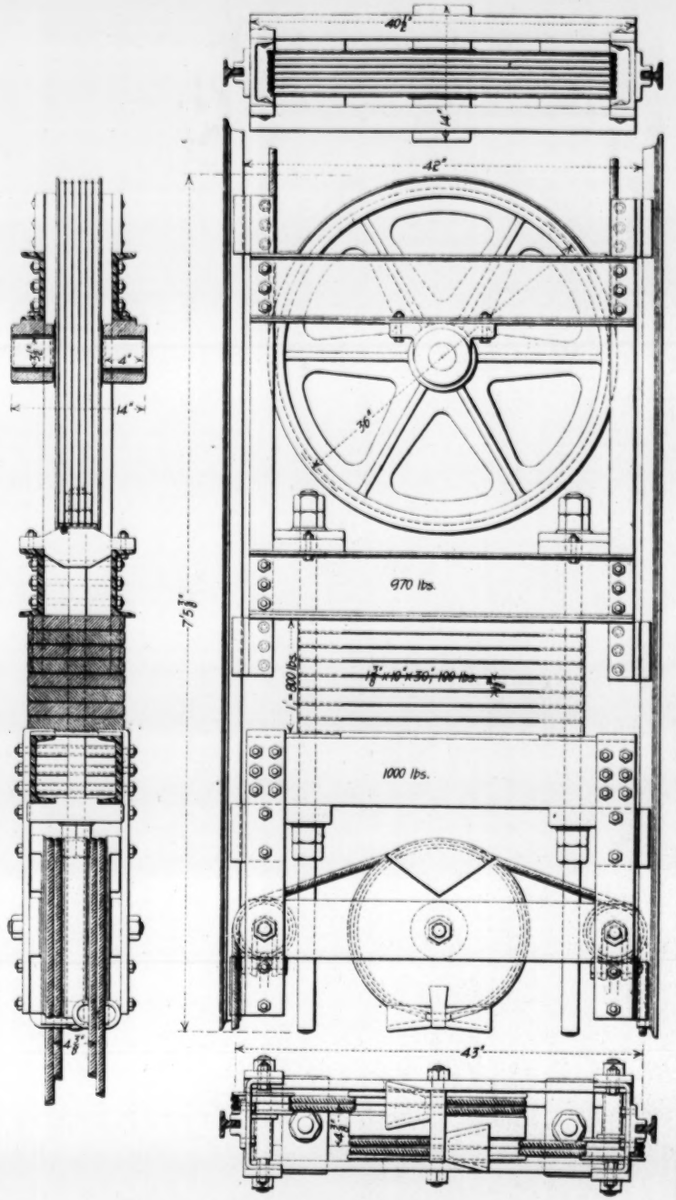
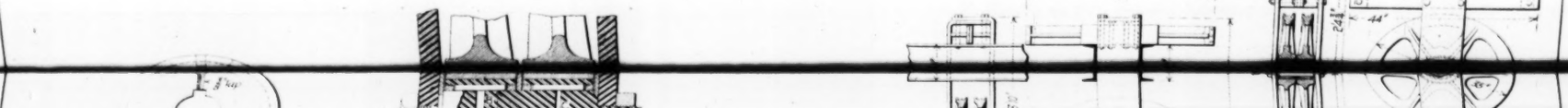


FIG. 4. DETAILS OF SHAFT COUNTERBALANCE.



Admiral Melville now comes forward, however, and shows that the triple screw is superior to the twin screw in economy, efficiency, and, indeed, in almost every particular, for use on any modern high-power war vessel of large size. We reprint in another column a condensation of Admiral Melville's paper, and regret that the limitations of our space prevent our giving it in full. Even in the abbreviated form in which we present it, however, a very strong prima facie case in favor of the triple-screw arrangement is certainly made, and the arguments will receive the serious attention of all intrusted with the responsibility of warship design. It is interesting to note that, according to a statement in the paper, the newest sea-going men-of-war of the U. S. Navy will be fitted with triple screws, each screw being driven by a quadruple expansion engine, and the central engine having five cylinders.

It will be noted that the argument in the paper relates almost solely to war vessels, although at the close Admiral Melville suggests that the gain in the matter of safety might make it worth while to adopt triple screws on the fast Transatlantic greyhounds. His suggestion that there is a material reduction in efficiency in screws of very large diameter, is one which deserves full investigation by the designers of high-powered steamships. It seems reasonable to believe that the loss in friction between the water and the blade at the periphery of screws of large diameter must be very great. The additional thickness of the blades necessary to secure strength as the length of the blade is increased, means also an increased loss.

The revolutionary character of Admiral Melville's claims for triple screws may be appreciated when it is remembered that twin screws have been universally adopted in the British Navy, and that it has heretofore been generally believed by naval designers the world over that twin screws were in general to be preferred to triple screws. Our readers may be interested, as we were, to learn how Admiral Melville's paper would be taken by the august body before whom it was presented. From the reports of the discussion in our English exchanges, we learn that among those who took part were, Mr. A. E. Seaton, Prof. Biles, Sir W. H. White, Director of Construction of the Royal Navy; and Mr. Geo. Quick, Chief Engineer, R. N., all of them experts of the highest class. Their general attitude toward the paper was one of courteous skepticism as to the soundness of the claims made for the triple-screw system; and it was made evident that English naval designers are not likely to follow America's lead in the matter of triple-screw propulsion, at least for some time to come.

COMPARISON OF ELECTRIC AND HYDRAULIC PASSENGER ELEVATORS FOR HIGH BUILDINGS.

It may not be known to most of our readers that just across the street from the building in which this journal has its chief publication offices, is the highest office building in the world, and one of the largest as well. It is known popularly as the Park Row Building, and more properly as the Ivins Syndicate Building. A fair idea of its structural features was given by the description published in Engineering News of Oct. 8, 1896.

From the street the completed building towers up for 26 stories. On the Park Row side, facing the old Astor House and the Federal Post-Office, are two towers which spring from the corners of the main building and add four more stories, so that the building is generally credited with a height of 30 stories.

The problem of affording a rapid and safe means of reaching the upper floors of high buildings has been the subject of much thought. In fact, high buildings and proper elevator facilities are so intimately related that it is hard to say whether the modern elevator is responsible for high buildings or high buildings for the developmen of modern elevators.

With the early forms of elevators, where the height of lift was small, two types were developed, the drum elevator, in which the car-lifting cables ran up overhead and down to a winding drum, and the direct hydraulic lift, in which the car was mounted on the upper end of a vertical plunger, working in a long hydraulic cylinder. Both forms are still employed; their use in building, however, is restricted to places where high speed and great height of lift are not requisites.

The next form, and the one now generally installed for first-class passenger service, employs the principle of the common block and fall, or multiplying pulleys. If we imagine one pulley block, with several sheaves to be anchored part way up the elevator shaft, and a similar block attached to the end of the piston rod, of a powerful hydraulic cylinder, and that a rope passes back and forth over these sheaves with its free end carried up overhead and down the shaft to the car, we have a clear idea of what is called the "multiple sheave" elevator system. Of course, it is apparent that to move even a light car with this arrangement requires the exertion of great force upon the piston; but on the other hand the car moves several times as fast and as far as the piston, perhaps five, ten or twenty times as fast, according to the number of sheaves in the blocks.

In operating this type of elevator the movement of the piston is under the control of the car operator and is effected by admitting water under considerable pressure to one side or the other of the piston in the hydraulic cylinder, the valve being moved by a rope passing through the car or attached to a wheel or lever inside the car.

With the general introduction of electric power a decade ago, a demand arose for elevators which could be operated by electricity. The attachment of an electric motor to the winding-drum elevator was a simple matter, but for high-speed passenger service the multiple-sheave hydraulic elevator had no competitors. Two well-known engineers thereupon undertook the task of adapting the electric motor to operate the multiple sheave elevator. They substituted a screw with a ball-bearing nut traveling upon it for the piston-rod of the hydraulic elevator, and they worked out the details of a series of difficult mechanical problems in a manner which challenges the admiration of engineers.

In our issue of Nov. 24, 1892, when the Sprague-Pratt elevator was first perfected and the first two machines had been installed, we illustrated and described it. In the seven years which have elapsed since that time, many of these elevators have been put in service, and many changes and improvements in detail have been made. The adoption of this elevator for use in the highest office building in the world was made in the face of sharp competition on the part of the hydraulic elevator builders; and its final selection was a notable tribute to the perfection which the design has attained.

It may prove of interest to compare in a general way the hydraulic and the screw elevator systems to ascertain what prompted the engineers of this building to abandon what may still be considered as "orthodox" passenger elevator practice in favor of a system which still retains more or less of novelty.

In the examination of elevator systems there are at the very outset certain requirements which must be fully met before an elevator can be considered worthy of any attention, and these are of especial controlling force where office-building service is to be furnished. First and foremost comes the item of safety, and this calls for the employment of absolutely reliable devices to prevent accidents resulting either from carelessness on the part of passengers or operator, or from the derangement of any part of the machinery. This is followed closely by reliability, by which we mean, first, freedom from interruptions in service resulting from the need of minor repairs, and, second, the precision with which stops can be made. The first condition imposed must be met by reducing the number and complexity of parts and making all details of substantial and simple construction; the second is met by quick-acting and positive controlling apparatus and brakes.

Another requirement is economy in operation, a very desirable factor, but secondary, of course, to safety and reliability.

Of the two remaining items, compactness and small first cost, perhaps the most important is the former. It certainly is so in buildings where there are a number of elevators and where floor space is valuable.

Bearing in mind the several requisites just outlined, let us next compare the two forms of multiple sheave elevators. It will be understood at the outset that while differences of detail may exist, the two systems are practically the same and may be made identically the same from the car to the multiplying-sheaves. Either form, it will be noted, may be placed vertically or horizontally as desired.

Safety:—Both types of elevator have "limit stops," which prevent the car traveling too high or descending too low in the shaft, a "speed governor," to stop the car should a safe speed be exceeded, and "car safeties" or catches, to hold the car should its suspending ropes break. The screw system, however, has an additional safeguard in the operating switch which is placed in the car. This is arranged to instantly stop all machinery and bring the car to rest should the operator become frightened or let go of the switch. All forms of hydraulic elevators are operated by a hand rope, wheel or lever, which must be moved to stop the car, and accidents have sometimes resulted from the lack of this automatic stopping feature. With this stop device and the excellent design of the other safety features it is generally admitted that the electric screw elevator is at least as safe as its rival. Its record in service as well as the record of the best hydraulic machines shows a marvelous degree of safety, exceeding that probably of any other public conveyance.

Reliability:—This could be best settled by keeping records for several similar equipments of the times of shut down and the hours spent in minor repairs not requiring a shut down. So far as our information goes, no such records have ever been published. In the absence of such data it is worth noting that in a building where several elevators are installed each electric elevator is a complete unit by itself, and in cases where in addition to the generating plant of the building, current can be obtained from street circuits, a complete shutdown of the elevator service cannot occur, except under extraordinary conditions. On the other hand, a complete shutdown with a hydraulic system is quite possible, owing to the dependence of all the elevators in a building upon one, or, at most, two pumps, and a single system of storage tanks and pipes. Anything which stops the steam supply of the building stops the elevator service. Coming again to the reverse side, it is true that the electric system has more operating parts, and much more complicated machinery, more liable to injury by fire or water and to minor breakages.

Economy in operation:—In any given case a certain definite amount of work is necessary to raise the passenger and freight loads, and this is the same no matter what elevator system is employed. But the handling of this live load, as it may be called, requires the lifting of cars and counterweights and the movement of more or less machinery. In the standard forms of hydraulic elevators the machinery works, as it were, under a full load at all times, whereas the electric elevator works in proportion to its load, actually pumping current back into the line when the car descends fully loaded.

Again, the steam engines operating generators for furnishing current for the elevator motors will require considerably less steam than the pressure pumps (for hydraulic elevators, which are notoriously large steam consumers). These two items combined caused the electric elevator to be considerably more economical. The power developed by the engine is transformed into electrical energy with a total loss not exceeding about 14%, a loss fully equalled by the friction of the water end of the pump and the resistance of the pipes. The average loss in the motors, controller, screw and nut will not much exceed the friction of the elevator piston-rod in the hydraulic system, when the current returned to the line by the motor is taken into consideration. The other losses are common to both systems.

Allowing for all possible losses, therefore, the electric system will certainly cost no more to operate than the hydraulic, and if a properly proportioned storage battery is installed to equalize the load on the engine and generator, a material saving over the hydraulic system can be safely counted upon.

Compactness:—The advantage of the electric system in this particular, especially when the

vertical type of machine is installed, is admitted even by advocates of the hydraulic system. For example, the entire operating machinery (except the engines and generators) of the eleven large passenger elevators of the Park Row Building could be placed in and operated from a room 15 ft. square.

First cost:—The question which system costs least to install is a disputed one, but one which can be easily settled, in any given case, by asking bids from makers of the different types. Such information as we have been able to obtain indicates that the cost of the two systems does not greatly differ. As the electric system and the principal hydraulic systems are now under the control of a single corporation, the price which the purchaser will have to pay for elevators of any type is something on which definite statements are not possible. It has even been rumored that the new elevator combination might decide to withdraw the electric multiple-sheave machine from the market. In view of the mechanical excellence which this machine has attained, however, such an outcome of the recent combination would be unfortunate, and would furnish another argument for those who contend that such consolidations are a barrier to progress and against public policy.

LETTERS TO THE EDITOR.

The Calculation of I-Beam Grillage Foundations —Correction.

Sir: Referring to my article "The Calculation of I-Beam Grillage Foundations," published in your issue of April 20, I wish to correct the following printer's mistake which I noticed in the formulas:

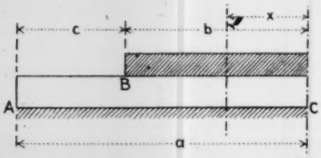
Formula (2)

$$M_x = \frac{x\,p}{2}\left\{a^2 - x^2\left[\frac{a}{b} - 1\right] - a\,b\right\},$$

should read

$$M_x = \frac{p}{2}\left\{a^2 - x^2\left[\frac{a}{b} - 1\right] - a\,b\right\},$$

In formula (3) M_{max}, the same x should be left out.



The accompanying sketch explains these formulas somewhat more fully than the original illustrations.

Yours truly, J. B. Nau.

134 West 83d St., New York, April 21, 1899.

The Architecture of the Bonn Bridge.

Sir: In regard to your editorial of April 20 on the arch over the Rhine at Bonn, I would say that from the Anglo-Saxon point of view what you say concerning the decoration by grotesque figures of a serious engineering work of such great importance is perfectly true. According to German ideas and prestige, however, such decoration is appropriate.

There is, however, an engineering feature which might be criticised and of which you make no mention. That is the curving of the chord members to conform to the curve of the chord, which necessitated an increase in the area of some of the members of 20%. I think no American engineer of prominence would sanction such an additional complication in the determination of the stresses, especially for a form of truss full of difficulties and uncertainties. Even for a much simpler form we have been known to add to the chord areas something for uncertainties in calculation. Yours truly,

Alex. Rice McKim.

106 East 23d street, New York, April 22, 1899.

(The figures used in the decoration of the Bonn bridge are hardly grotesque, as that word is ordinarily used. In fact, the grotesque, if rightly and artistically used, is not inappropriate to the decoration of dignified structures, as may be seen by the effective use of griffins, dragons, and other grotesque creations of the imagination in the decoration of many of the world's masterpieces of architecture. The figures on the toll-house of the Bonn bridge are objectionable because of their triviality, and because they appeal to one's sense of the ludicrous, whereas the decoration of a dignified structure should arouse the nobler emotions of the mind. A scene from the "Fliegende Blatter," or the American "Puck," might be very appropriate in the decoration of a playhouse; but it would be absurd to use it to ornament a city hall.

The portal decorations of the Bonn bridge are less objectionable, because they were intended to be emblematic; but here the mistake was made of crowding a mass of little pictures (which were not conventionalized enough to give them dignity) upon a massive member of a great bridge. The effect was as incongruous as it would be to fasten a lot of campaign buttons upon a noble bronze statue.—Ed.)

THE LOGICAL ARRANGEMENT OF THE MOTIVE POWER OF WARSHIPS.*

By George W. Melville, Engineer-in-Chief, U. S. N.

In the preparation of a set of tables showing the power required to drive a vessel of a given displacement at a given speed, the results of about 200 trials of nearly as many ships has been used. From this set of tables there was developed the remarkable fact that the propulsive efficiency of vessels with three screws is, in almost every case, above that of ships of approximately the same size, speed and general lines, but fitted with but two sets of engines. Attention has heretofore been drawn to the remarkable performance of the U. S. cruisers "Columbia" and "Minneapolis" on their trials. It has been very interesting to those who were responsible for the plans of the machinery of these vessels to see how well they have maintained their position in the front rank of naval vessels. These five-year-old ships, ten years old in design, are still among the most economical vessels in the world's navies so far as propulsive efficiency goes.

It was not possible, at the time of the design of those vessels, to obtain, in the United States, sufficiently large forgings for such great power as it was desired to install, if the twin screw system were adhered to. To-day the conditions have changed, and we have examples of engines of about the power we desire to use for our fastest ships already constructed in the United States and giving complete satisfaction. The science of metallurgy has made such progress in the last decade that we are now able to specify regularly steel of 95,000 lbs. tensile strength, 21% elongation in 2 ins., and to stand cold bending to an inner diameter of 1 in., without showing cracks or flaws. Improved methods of forging, our more thorough knowledge of fluxes, the exclusive use of nickel steel for high grade engine construction, the judicious employment of annealing and tempering—all these, combined, enable us to secure stronger materials; and now we obtain a vast increase of power without a much greater weight than that required ten years ago for the lower powers then prevailing. The reduction in weights is most apparent in the moving parts. This is an important point, as it has meant that the growth in power has not been accompanied by an increase in vibration, a matter that is likely to limit speeds of rotation in the future. We are no longer forced to divide the power among three shafts because of the impossibility of obtaining one sufficiently large to transmit half the power.

There are many other considerations, however, both tactical and engineering, which make it still advisable, at least for the highest powers, to use the triple screw method of propulsion for our men-of-war.

The most evident advantage from the use of three screws is the consequent subdivision of the power. This is of particular moment on war vessels where the possibility of disaster in battle is to be considered as well as that of accident in time of peace. Not only does the increased number of engines decrease the probable amount of power that may be disabled at any time, but also the chance of fatal injury to the ship, through its motive machinery, is greatly lessened.

Should one of the propelling engines be disabled there is not nearly as much interference with what is called the handiness, the steering qualities, of the ship, if there are three screws, as if there be but two. With twin screws, and one only in use, it is necessary, in order to keep the vessel on her course, to use a helm angle of from 6½° to 10°. This is the amount when the screw of the idle engine is left to revolve freely. We have attempted to get over this difficulty by using diverging shafts and thus reduce the turning effect of the engines; but this is objected to by the deck officers, who wish vessels which can readily "turn on their heels." Of course, the less the friction of the power that is disabled, the less the ill effect on handiness.

One of the greatest advantages from the use of triple screws is that smaller propellers are required for the same total power. This particular in itself presents sufficient advantages to justify the use of three engines on warships, and it is surprising that this point has not been more thoroughly developed. A very large part of the loss of power at the propeller is due to the frictional resistance of the water to the passage of the propeller blade. This resistance increases with any increase of the peripheral speed of the blades, and low speed will be advantageous in this regard.

With very high speeds and powers this speed is now very near the critical point beyond which the friction is excessive, and the effects of cavitation begin to be felt. The decrease of pressure upon the forward sides of the screw blades, at high velocity, is not a negligible quantity.

The use of three screws allows a reduction in diameter of screw of over 20%, and while, as will be pointed out, this is accompanied by an increase in the number of revolutions, the speed of periphery may readily be reduced below what is required in twin screw practice.

At the stern of the ship, amidships in the following wake always present to some extent with the most carefully designed hulls, the effects of a large screw are not so signally bad. I think that "cavitation," or the tendency thereto, is greatly reduced in this following wake, and, on that account, I believe that a considerably greater efficiency is obtained from the screw at the stern post than from those on the quarters. Whatever the cause, this increase in efficiency is so well shown by the results of trials that it can no longer be questioned.

Investigation along this line has not yet proceeded far enough to enable me to give more than tentative figures as to the propulsive efficiency due to the different methods of arranging the screws. It is, however, certain that there are gains both from the use of small screws, and of a screw working in the following wake, and that these gains would naturally grow with an increase in speed. Speaking only of full power trials, it will probably be found that up to some low speed not yet determined it will be best, from the economical standpoint only, to use a single screw; beyond this point, it will be found that the use of twin screws would tend to a reduction in the power required for a given hull and maximum speed, and that, at any time, where twin screws are good, triple screws are better. I estimate the average economy over single screw ships, from the use of twin screws, as about 8% for vessels of maximum speeds from 12 to 20 knots, and I consider that triple screws are more economical than twin screws by from 5% for 15-knot ships to 12% for those of 24 knots speed. These figures are approximate; but they are from trial data of many ships fitted with the different methods of screw propulsion.

In ramming an enemy, if all goes well, there would be little difference between the twin and triple systems, but a glancing blow from either forward or aft would certainly take off the enemy's side screw if, as in twin practice, it projected beyond the counter; and, later on, as the ships rubbed past each other, one's own side screw would be broken, under the same condition of projection. But, with a small screw, such as can be had in the triple system, neither propeller would be damaged, and the stern screw would be safe in any event. This point is of value, too, in ordinary cruising where a floating log, or a pile in a river would disable a propeller of a twin screw ship, while the obstruction would have been pushed clear of the smaller propeller of a triple screw by the ship's hull. Going alongside dock also—that bugaboo to commanders of high-powered, fine-lined, speedy twin screw vessels—would be made much easier.

The shorter shafting required for getting the smaller propellers clear of the ship would allow these screws to be placed further forward, where they would be better protected by the hull. This shorter shafting would also decrease the strains on the propeller shafting in bad weather, and would often obviate the necessity of an extra supporting strut, giving, as well, a decreased danger of fracture and the possibility of decreasing the weight.

The fact that, with small screws the tips of blades are lower in the water than with the twin screw system gives advantages. The design of the upper and fuller stream lines could be considerably freer. If it is considered advisable (and I have no doubt the hull designers will show that this gain is not of great moment where a central screw is fitted), this advantage could be passed over in favor of giving the wing shafting a slight inclination upward, so as to obtain a horizontal thrust when the stern of the vessel settles in the water, at full speed. Ordinarily, however, the squatting of the ship would be insignificant. The fact must not be overlooked that the lower propellers are placed the freer the access of water, and the more perfect the action of the screw.

With tips of blades well buried, the danger of racing is decreased, each extra foot of immersion reducing it. Any one who has stood by the throttle, checking the engine with the heave of the ship, appreciates fully this advantage. The central screw, of course, would never race except in a sea where the ship was pitching heavily; while the side screws, being well forward and deep in the water, would probably never give trouble in the worst of seas.

When the use of three screws was first proposed the idea prevailed in the minds of most engineers that the "race" of the water from the side screws would materially affect the action of the central screw. The error of this supposition was fully shown by the trials of the "Columbia" and "Minneapolis." In the "Columbia" the pitch of all screws was made the same. The trials of this ship having shown the revolutions of the central screw to

*Condensed from a paper read before the British Institution of Naval Architects, March 23, 1899.

be less than those of the wing screws, the pitch of the central screw on the "Minneapolis" was made 6 ins. less than that of the side screws. On the trials of the latter vessel the speed of rotation of the central screw was almost precisely a mean between the speeds of the two side screws, which differed slightly in pitch. This result was obtained without any "jockeying" of the throttle or change in the cut-off.

In the design of marine machinery it is important that the ratio between the stroke and the diameter of cylinders be kept sufficiently high. The ratio is necessarily low in all naval vessels as compared with the merchant service on account of the necessity of keeping the machinery below the protective deck. Of course, the larger the power and size of the low pressure cylinder the longer the stroke should be, and therefore the greater the height of engine room required for a properly designed engine. The greater the draft of the vessel the greater the possible height of the engine room, and, for the same number of revolutions, the greater the piston speed. It is unquestionable that, where more than, say, 10,000 horse-power is to be transmitted through a single shaft, under present conditions of speed and displacement, the number of revolutions will be limited by the propeller. We in the United States Navy, having ships of very light draft, as compared with other fleets, are most hampered in this regard.

It is to be noted, also, that the economy of a triple screw ship is developed not only in more efficient propulsion, but also in the more efficient use of the steam in the engine due to the decreased condensation following the increased number of revolutions and the greater piston speed. The economy of propulsion is thus increased as a result of both increased propulsion efficiency and of increased efficiency of the engines. A decreased total weight of the machinery is also a natural result of the use of triple screws.

To obtain a proper conception of the advantages of triple screw propulsion, it is necessary to consider, also, the latitude afforded by this system in the methods of running the ship under cruising conditions since either one, two or three screws may be used. There have been many trials of triple screw ships under each of these methods of propulsion, and it may be interesting to give a few of the results which have not hitherto been published so far as I am aware. Taking a vessel of, say, 12,000 tons, 23,000 HP., and 22 knots speed, when all engines are used at full power it is found that:

1. The power required to drag one screw, uncoupled from the engine and left to revolve freely, is 150 HP. at 10 knots; 600 HP. at 15 knots.

2. If coupled to the engine, at 10 knots speed the power absorbed in dragging is slightly in excess of 300-HP.

3. If two screws are dragged, the loss from drag is practically double what it would be with one idle screw for the same speed of the ship.

4. The loss in power due to condensation in an engine (not the result of expansion of steam in the cylinders, but attributable directly to the heating of the cylinder walls), is almost exactly 1 lb. of steam for each HP. of the maximum power for each engine. This figure is approximately correct for all speeds, increasing slightly for the lowest speeds. It applies to jacketed engines.

5. With three equal screws, the center propeller has not sufficient area to give economical results when used alone at speeds above eight knots. With three equal screws, the use of the two wing propellers alone can be depended on to give a considerable gain in economy for all speeds from 8 to 17 knots inclusive. These results have been gathered from fully authenticated trials, not only of our own ships, but also of triple screw ships in other navies.

All screws were practically equal in disk area in the trials from which these results are obtained.

With these points known, the problem of the design of triple screw ships is greatly simplified. The disadvantage of the drag of a screw is measured, and the advantage of the fitting hitherto adopted, which provided for the disconnecting of any idle screw from its engine is clearly developed.

If three screws are to be fitted to a warship, and the design is to conform to the conditions of economical propulsion obtaining on these vessels, as shown by our present knowledge of the effects of three screws upon propulsive and engine efficiency, there appear to be but two practicable arrangements. The central engine should be considerably more powerful than either of the wing engines, or it should be considerably less powerful. This follows from the fact that a propeller design which will give in one screw sufficient area for the ordinary cruising speeds up to 12 knots is nearly impossible if the same screw is designed to be worked as one-third of the propelling system for the highest speed of the ship. The proportions of the screw must be changed to suit the latter conditions. It is evidently not wise to use as much as two-thirds of the full engine power for cruising at one-tenth power. The use of three equal engines is therefore out of the question as far as comparative economy goes. If a small center engine be used, it would be practically an auxiliary. A very large screw necessarily being fitted to secure a fair propeller efficiency at low speeds, when the small engine alone would be used, it would be of practically no value at the highest speeds. I consider, therefore, that it would be far better practice to use a large center, and two small, wing engines, in which design under no conditions would there be a useless engine.

Of course, either of these plans involving the use of two different sizes of engines on the same ship is disadvantageous, but this disadvantage is not so great as a casual view of the conditions would seem to indicate. Engines do not break down in service. Careful designs for the maximum power insure good working of the machinery. Accidents to the engines are extremely rare, and are due almost invariably to some defect in a seemingly unimportant detail. The engine itself, so far as its large parts are concerned, does not break down, and a supply of the lighter spare parts provides for all emergencies such as are ordinarily met.

On the other hand, it is well to note the many advantages due to the use of different engines. There is, in particular, much to be said in favor of the plan of installing small wing engines in a triple screw ship. It is a fact that commanders of our ships hesitate, as naturally they should, to enter or leave a port with only one screw in use. They desire to retain the practical advantages of handiness accompanying the use of twin screws. It is, further, a fact that ships which ordinarily cruise at speeds of from 14 to 16 knots we have found to make better speeds, in time of war, than ships of the same class but of lower cruising speed. These conditions, combined with the proved efficiency of the use of the wing engines at speeds up to 17 or 18 knots, have been, with us, the determining factors in causing the adoption of designs involving the use of the smaller wing engines. It has been found advisable to fit economical machinery for cruising at speeds as high as 10 knots. While engines which will be most economical at this speed will not be the most desirable in this respect, for a speed of ten knots, they will retain considerable advantage over any other system, in the reserve which will be ready for instant use.

To reduce the engine room space it is advisable to place engines abreast in the ship. It is also a great advantage to arrange the engines in this way, as it makes possible the placing of a part of the boiler power abaft the engine, which gives easy solution to all problems connected with the change in trim due to the use of light water tube boilers, and also reduces vibration by placing the engines in the strongest part of the ship. In fact, the center and most powerful engine is exactly at the point of greatest resistance of the hull to vibration. By using smaller wing engines it is also easier to arrange the engines abreast than it would be to install twin screw engines of the same total power. This follows from the lozenge shape of the space available for the engine rooms beneath the sloping protective deck and above the rising bottom of the ship. Again, but one screw is dragged with the two engines in use. This screw is a large one, it is true, but the drag is probably not so great as it would be with two smaller screws of the same total power.

It is also regarded as an advantage for this system that there is always one-half the full power available in case of accident. The center engine is seldom used, and our experience goes to show that it is always in a condition of very good efficiency. The customary employment of the smaller wing engines insures ease of making the regular repairs. It is but fair that I should state that, with its very large screw, designed for transmitting about half the total power at full speed, the use of the center engine alone may prove slightly more economical than that of the wing screws for a speed of about ten knots, this superior efficiency following from the working of the screw in the following wake. I do not expect, however, that the center engine will often be alone employed, as the maneuvering qualities and general handiness of the ship are so much improved by the use of two screws at all times. It should, however, be pointed out that the handiness will be retained at full power, and will not be affected badly by the reduction in the size of the wing engines.

It may naturally be inquired why the superior efficiency due to the use of triple screws has not led to their general adoption in the merchant marine. Triple screws undoubtedly would have been used in that service if the conditions obtaining were the same as those existing in the navy. Merchant vessels, however, instead of running at variable speed, are always worked at their full power, and there would be consequently no advantage to their owners in fitting machinery capable of working economically at low speeds. The stroke of engines in these vessels is, also, not limited by a protective deck, and it is always possible with them to obtain the great piston speed necessary for economy by increasing the height of the engine. We see, therefore, that two of the main reasons for the use of triple screws in men-of-war do not obtain in the merchant service. Added to this must be the fact that the cost of building and installing three engines when not all of the same size is considerable greater than that of two engines of the same total power; and also that the cost of maintenance due to the larger force required would be considerably increased. From these considerations it would appear that triple screws may not be desirable for the merchant service under present conditions of size and speed. I think, however, that any Transatlantic line which would definitely adopt the triple system would be patronized by a considerable number of persons because of the greater security afforded by its use.

COMPRESSED AIR MAINS FOR RAILWAY BLOCK SIGNALS AND INTERLOCKING PLANTS.

At the meeting of the Railway Signaling Club on April 25, a paper on the above subject was read by Mr. A. M. Keppel, Jr., Supervisor of Signals, Pennsylvania R. R. We abstract the following data from this paper:

The compressed air mains on the main line of the Pennsylvania's Pittsburg Division, now extend from Pittsburg eastward 63 miles. Most of it is laid underground in wooden boxes; but in 1884 one mile was supported by stakes about 3 ft. above the ground. This pipe is now nearly as good as new, while three miles laid underground at the same time is in very bad condition. In the pipe laid in 1884 and 1888, globe valves were used, and pipe bent in the form of a loop was used for expansion joints. In 1891 10 miles was laid, and in 1898 18 miles, all of which has gate-valves and slip expansion joints placed every 1,000 ft. The motion in these joints is about 1 in. each way for every 50° change in temperature. The boxing or trunking is made of rough white and yellow pine; bottom, 2×4 ins.; sides, 2×6 ins., and cover, 2×8 ins. All pipe is galvanized, partly to make the pipe a better conductor, as it is used to some extent for a return circuit, and partly to prevent the rust on the inside which takes place with black pipe and cause scaling and dirt, which reaches the valves.

The pipe is now laid between the tracks and with the tops of the foundation blocks on which the trunk rests about 20 ins. below the top of the rail. Where switch ties or timbers cross the space between tracks a right angle turn is made to the outside of the track and back again beyond the obstruction. A 90° bend with 30 ins. radius was used at these points. Expansion joints are boxed in to facilitate expansion. The 3-in. mains laid in 1898 cost in the ground an average of 32.37 cts. per lin. ft., the pipe itself costing 19.7 cts. per ft. The compressed air is supplied by Norwalk standard steam-actuated compressors.

The principal trouble with the mains has been their obstruction by frost and ice in the winter. Previous to 1895 obstructions of this sort were of almost daily occurrence. Small reservoirs were then attached to the main pipe at intervals, and collected a large amount of moisture, yet did not obviate the difficulty. A cooling coil was then placed at the compressor to cool the air before its flow in the mains, and its working has been very satisfactory. The cooling coil consists merely of 90 ¾-in. pipes, 11 ft. long, connected to longer distributing pipes so that the flow from the compressor can distribute itself equally through the pipes.

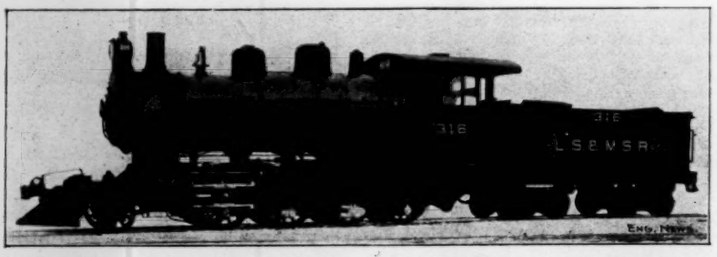
GAS AND GASOLINE ENGINES of 125-HP. and 80-HP., respectively, have been built by the New Era Iron Works, of Dayton, O., and are said to be the largest single-cylinder engines of their respective motive powers ever built. The former is in use at a brickyard near Allegheny, Pa., and the latter at Columbus, O. They are both on the four-cycle system. The ball governor is driven at high speed by gearing, and rests upon the fuel valve, admitting a light or heavy charge, according to the load on the engine. There are three valves, moving vertically and having their stems operated direct by cams on the shaft underneath. A special feature of the gas engine is the exhaust arrangement. The piston on its outer power stroke uncovers a valveless port in the side of the cylinder, allowing free escape of the burnt gases to the exhaust pipe or chamber. This reduces the pressure in the cylinder so that no power is required to raise the exhaust valve at the head of the cylinder on the return stroke, and makes this valve free from the effects of the hot gases.

25-FT. CAST-IRON DRUMS have recently been made for large hoisting engines, and are interesting examples of foundry work. The shell consists of three separate castings, two being conical end sections and the third a cylindrical middle section. The former are 7 ft. 3 ins. long and 16 to 25 ft. diameter, each section having 33 spiral grooves which will hold 2,1.0 ft. of rope. The middle section is 7 ft. 1¾ ins. long and 25 ft. diameter, with 49 spiral grooves, the total capacity of the drum being 8,125 ft. of 1½-in. rope in single coil. The shell is only ⅞-in. thick at the bottom of the grooves, and 35 tons of iron were poured to form each section. The casting was done in a loam mold, and the core weighed about 100 tons, over 37,000 bricks being used in the mold and core. After casting, each section was cut into six segments for convenience of shipment, the segments being bolted together by interior flanges and mounted upon a series of spiders.

NEW LOCOMOTIVES FOR THE LAKE SHORE & MICHIGAN SOUTHERN RY.

The Lake Shore & Michigan Southern Ry. has long been noted for adhering to light-weight locomotives, while other roads have been putting much heavier engines in service. It has recently added to its equipment, however, a number of engines of greater weight than have been hitherto used, although the weights are in no way remarkable, being only 156,500 lbs. for the consolidation and 154,000 lbs. for the ten-wheel engines. The new equipment includes 15 consolidation freight engines, 15 ten-wheel freight engines, and 15 six-wheel switch engines. All of these were built by the Brooks Locomotive Works, of Dunkirk, N. Y., and we are indebted to the builders for photographs and other information.

The consolidation engines, shown in the accompanying cut, are compact and fine-looking machines. The boilers are of the extended wagon-top type, with bell on the boiler barrel, sandbox on the throat sheet, and dome and safety valves



CONSOLIDATION LOCOMOTIVE; LAKE SHORE & MICHIGAN SOUTHERN RY.
G. W. Stevens, Superintendent of Motive Power; Brooks Locomotive Works, Builders.

on the wagon-top. Steps are fitted to the barrel for convenience of access to the sandbox, and might well have been added to facilitate access to the headlight. There is one step on the smoke-box, and with this and the two hand rails a man can manage fairly well, but the arrangement might easily be improved. The engines will burn bituminous coal, and have long fireboxes with brick arches mounted on water tubes.

Double-bar alligator guides are used, with connecting rods of I-section, while the coupling rods are of rectangular section, slightly fishbellied in shape. The Gould M. C. B. automatic coupler is fitted to the engine pilot and the tender. Other fittings include compressed air bell ringers and sand jets, United States metallic packing for the piston rods and valve stems, Ashton safety valves, French & Co.'s springs, and Nathan injectors and sight-feed lubricators.

The general dimensions of these new consolidation engines are as follows, given in our standard form:

Consolidation Freight Locomotive; L. S. & M. S. Ry.

Running Gear:	
Driving wheels, (8) diameter	4 ft. 8 ins.
Truck wheels (2), diameter	2 " 9 "
Tender wheels (8), diameter	2 " 9 "
Driving wheel centers	Cast steel.
Journals, main driving axle	9 x 12 ins.
Coupled axles	8½ x 12 "
Wheelbase: Driving	15 ft. 9 ins.
Total engine	24 " 0 "
Engine and tender	52 " 0¼"
Length over engine and tender	62 " 0¾"
Weight in Working Order:	
On driving whls, 138,500 lbs.; on truck wheels	18,000 lbs.
Engine total	156,500 "
Tender loaded	93,900 "
Cylinders	Two.
Diameter and stroke	20½ x 28 ins.
Form crosshead and guides	Two-bar "alligator."
Connecting rod, length between centers	10 ft. 11 ins.
Side rod	Solid ends.
Valve Gear: Type	Link.
Ports, steam 1⅜ x 18 ins.; Ports, exhaust	3 x 18 ins.
Bridges, width	1½ "
Slide valves	Richardson balanced.
" " maximum travel	5¼ ins.
" " inside lap	(none.)
" " outside lap	1 in.
" " lead in full gear (negative), variable	1-16-in.
Boiler: Type	Extended wagon top.
Barrel, diameter, inside smallest ring	5 ft. 4⅛ ins.
Dome, diameter	2 " 8 "
Thickness, barrel plates	⅝-in.
" smokebox tube plate	¾-in.
Horizontal seams	Sextuple.
Circumferential seams	Double.
Height from rail to center line	9 ft.
Length of smokebox, including extension	5 ft. 4 ins.
Spark arresting device. Wire netting, mesh	2½ x 2½ "
Working steam pressure	180 lbs.
Firebox: Type	Over frames.
Length, inside, 9 ft. 6 ins.; width inside	3 ft. 6 "
Depth at front, 6 " 6 "; depth at back	6 " 3 "
Thickness, side and back, plates	5-16-in.
" crown plate	⅜-in.
" tube plate	⅜-in.
Crown stays, Radial; Grate bars	Rocking.
Is fire-brick arch used? Yes; on water tubes.	
Water spaces, width at front	4 ins.
At back and sides	3½"
Tubes, Charcoal iron; Number	286.
Thickness	No. 11 B.W.G.
Diameter, outside	2 ins.
Length over tube plates	13 ft. 3 5-16 "
Heating Surface and Grate Area:	
Heating surface, tubes (interior area)	1,971 sq. ft.
" " firebox & fire-brick arch tbs	212 "
" " total	2,183 "
Grate area	32½ "
Miscellaneous:	
Exhaust nozzle; single and permanent; diameter	5¼ ins.
Exhaust nozzle, distance below c. line of boiler	6½ "
Smokestack, diameter at top and base	16 "
" height above smokebox	2 ft. 10½"
" height of top above rail	14 " 8 "
Capacity of tender tank	5,000 galls.
Capacity of coal space	8 tons.
Brake fittings:	
American on drivers; Westinghouse, tender and train.	
Tender tank: Length	20 ft. 4 ins.
Width	9 " 5 "
Height (exclusive of collar)	4 " 4 "
Plates	3-16 and ¼-in.

The ten-wheel engines are very similar to the consolidation engines, except that the rear truck wheels take the place of the forward drivers, and the two leading coupled axles are placed further forward, being almost directly under the dome and sandbox. They also have the unusually long piston stroke of 30 ins. The coupling rods, as well as the connecting rods, are of I-section on these engines. The switch engines have straight boilers, with large domes, and a sandbox at each end of the barrel. The rear axle is the main driving axle, which necessitates the use of a long connecting rod. These rods are of I-section, while the coupling rods are of rectangular section. The leading dimensions of these engines are as follows:

	Engines, 10-wheel.	Switch.
Driving wheels	5 ft. 2 ins.	4 ft. 4 ins.
Truck wheels	2 " 9 "	.....
Wheelbase, driving	15 " 0 "	11 ft. 3 ins.
Wheelbase, engine	25 " 6 "	11 " 3 "
Weight on drivers	120,000 lbs.	124,000 lbs.
" total engine	154,000 "	124,000 "
" tender, loaded	99,100 "	79,000 "
Cylinders	19½ x 30 ins.	19 x 26 ins.
Boiler, diameter	5 ft. 4½ ins.	5 ft. 4 ins.
Working pressure	180 lbs.	170 lbs.
Firebox	114 x 42 ins.	80 x 34⅛ ins.
Tubes, number	286	246
" diameter	2 ins.	2 ins.
" length	13 ft. 3⁹/₁₆ ins.	14 ft. 6¼ ins.
Heating surface, tubes	1,971 sq. ft.	1,856 sq. ft.
" " firebox	202 "	163 "
" " total	2,173 "	2,019 "
Grate area	32½ "	18½ "
Water	5,000 gallons.	3,500 gallons.
Coal	8 tons.	5 tons.

The tenders of all the engines have frames built up of steel channels, and are mounted on diamond trucks fitted with elliptic springs. The tenders of the switch engines have inclined or "swallow-tail" tanks, with a shield round the short coal space to enable the coal to be piled up. A rack or gate across the front of the coal space keeps the coal from getting down on the tender deck.

THE REPORT OF THE ST. LOUIS COMMISSION ON THE CHICAGO DRAINAGE CANAL.

We have recorded from time to time the public agitation in St. Louis regarding the effect of the Chicago Drainage Canal upon the Mississippi River, from which St. Louis draws its water supply. The discussion of the subject finally resulted in the appointment of a committee of four business men and four city officials to report on the questions involved. The committee has considered at length both the local bearings of the question and the broader matters of general expediency and legality of the work as a whole, in its relation to Chicago and to the Illinois and Mississippi valleys. In fact, it goes further than this, and discusses briefly some of the established engineering and legal principles in relation to stream pollution, which are of wide general application and interest. In view of the magnitude of the work discussed, the composition of the committee, which includes several prominent engineers, and the assertions of the report that the drainage canal is bound to be a colossal failure, and may lead to interstate and international complications, we have taken space to print the report in full. We are indebted to Mr. M. L. Holman, M. Am. Soc. C. E., Water Commissioner of St. Louis, for the text of the report, which is here presented:

St. Louis, April 7, 1899.

Hon. Henry Ziegenhein, Mayor of the City of St. Louis

Sir: In accordance with your invitation of Nov. 12, 1898, Messrs. Henry C. Haarstick, representing the Merchants' Exchange; W. K. Kavanaugh, representing the Business Men's League; E. C. Rowse, representing the Real Estate Exchange; Julius Lesser, representing the Cotton Exchange; Robert E. McMath, President of the Board of Public Improvements; M. L. Holman, Water Commissioner; B. H. Colby, Sewer Commissioner, and Dr. Max C. Starkloff, Health Commissioner, met at your office and organized as a commission for the investigation of the plans proposed for the disposal of Chicago sewage. Robt. E. McMath was elected Chairman, and E. C. Rowse Secretary of the Commission. Subsequent meetings were held in the office of the Board of Public Improvements, and the minutes of these meetings accompany this report.

In the absence of instructions, we have felt ourselves at liberty to examine the plans proposed for the disposal of Chicago sewage through the Sanitary and Ship Canal, and the probable effects of the operation of the Canal, not only upon St. Louis, but Chicago and the intervening territory.

The Chicago Sanitary and Ship Canal has been dug from the South Branch of the Chicago River to the Desplaines River at Lockport, and it is proposed to reverse the flow of the Chicago River and discharge it through this Canal; and it is further proposed to intercept all of the sewage of the City of Chicago, now flowing into Lake Michigan, and deliver it to the Chicago River and to the Canal. This operation, if successful, will deliver the entire flow of sewage of the City of Chicago into the Desplaines River at Lockport.

It is further proposed, in order to mitigate the nuisance existing from the flow of sewage, to add a volume of water from the Lake at the rate of 20,000 cu. ft. per min. for each 100,000 inhabitants of the Sanitary District.

The Chicago Sanitary and Ship Canal is being constructed under the provisions of an Act of the Legislature of the State of Illinois, entitled: "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois rivers."

Under authority of this Act, the Sanitary District of Chicago was organized, and under the powers of the Act, the Sanitary District has constructed and expects to operate the Canal. The Sanitary District of Chicago and the city of Chicago are two distinct corporations. They cover in large part the same territory, but the boundaries are quite different. The city includes much territory that is not in the Sanitary District, and the Sanitary District includes territory which is not in the city. The chief reason for creating the Sanitary District was that Chicago had a debt to the constitutional limit of 5% of assessed value, and by resorting to the device of a Sanitary District the new organization could borrow money for corporate purposes to an amount not exceeding 5% of the aggregate of assessed valuation of taxable property in the district.

The occasion which induced resort to this subterfuge to avoid the restraint of the constitution, was that the discharge of sewage into the Chicago River and directly into Lake Michigan produced an intolerable nuisance in the river, and to some extent along the Lake front. In times of heavy rainfall, the contents of the river are emptied into the lake and more or less directly reach the intakes where the city's water supply is taken.

To the creation of the Sanitary District, the people of St. Louis took no exception. St. Louis has not objected to Chicago's undertaking, but has an interest in the result. The purpose soght by the Sanitary District may be legitimate, but it by no means follows that the way proposed to attain the purpose is either wise, on the part of Chicago, or just or even fair to other communities affected.

If it were brought forward as a new proposition to allow a great city to pass the contents of its cesspools through a smaller city and in front of several lesser towns, there can be little doubt that the outrageous proposition would be emphatically refused. The thing is no

less an outrage because it was allowed to have a beginning many years ago, and has been continued, though repeatedly and vigorously protested against.

We do not think it necessary to inquire whether Chicago could have found a better way to dispose of sewage than to turn it into the Desplaines. The natural contour of the country suggested two courses: One, to extend the Desplaines low level below Joliet to Chicago, and collect the sewage of Chicago unmixed with either lake, river, or surface waters, and discharge it below Joliet, taking advantage of the rapidly descending and expanding valley to purify the sewage by filtration, sedimentation or other treatment; the other course, to extend the lake level across the divide into the Desplaines valley and collect the sewage of Chicago, mixed with a greater or less quantity of lake water, and discharge the diluted sewage into the Desplaines River.

The promise of great business opportunities, docks, slips and manufacturing sites with shipping facilities, a navigable waterway and water power, by extending the lake level into the Desplaines valley, undoubtedly led to the adoption of the second course.

The Drainage Canal, as constructed, when put into operation according to present plans, will be a failure, unless it accomplishes four results: (1) Protection of Chicago's water supply from pollution. (2) Purification of the Chicago River and its branches. (3) Discharge of flood waters without overflow. (4) Disposal of all the sewage from the population centering in Chicago, without detriment to other communities. These ends must be accomplished without creating a current which will interfere with the movement of vessels in the Chicago River.

It is not necessary to discuss the probabilities of successful operation of the Canal to secure the results stated. The interest of St. Louis in the matter arises from the proposed use of the Canal to discharge sewage into the Desplaines River, Illinois River, and thence into the Mississippi River, about 45 miles above St. Louis. In this connection it must be clearly understood that Chicago sewage is now discharged in this direction, and has been for many years.

That Chicago was allowed to begin the discharge of sewage through the Illinois and Michigan Canal in 1871 may possibly be excused; but there can be no assent to the position that a vested right has been acquired. Even in the Act under which the work is being done, the State has expressly reserved the right to alter, amend or repeal the Act, or to impose conditions, restrictions or requirements, other, different or additional to any now imposed.

A mistake was made when the present plans were adopted, and the State of Illinois authorized a scheme which has for its basis the unwarranted assumption that sewage can be made harmless by the dilution proposed.

It is, therefore, a proper suggestion, in the light of the advance made in sanitary science since the Sanitary District Act was passed, that the Act should be amended and the condition imposed that Chicago purify its sewage before discharging it into the Desplaines River. That is practicable, but requires radical changes in the present plans of both city and Sanitary District.

Dilution of sewage has been practiced by Chicago for many years and has proven a failure. Results have been unsatisfactory, even as a remedy for the local trouble. The lowering of the summit level of the Illinois & Michigan Canal, completed in 1871, at an expense of $3,000,000, established a flow from the lake to the Chicago River and the Illinois & Michigan Canal to the Desplaines River at Joliet, stated to have been about 9,000 cu. ft. per min., differing from the present scheme in scale only.

At the demand of the sanitary authorities of the State, the sewage pumping station at Bridgeport was next provided, to increase the dilution from 9,000 to 60,000 cu. ft. per min., but the result was again unsatisfactory.

The State of Illinois now requires another dilution from 60,000 to not less than 300,000 cu. ft. of water per min., with the further provision that, at all times, a flow be maintained of not less than 20,000 cu. ft. of water per min. for each 100,000 of population in the district drained.

The Chief Engineer of the Drainage and Water Supply Commission of Chicago, in 1887, stated before a joint committee of Senate and House of Representatives of Illinois, in answer to the question: "What would be the proper dilution of the water so that it would be inoffensive to the smell and innoxious?"

> The English River Commission have made a very thorough examination of this question, and the amount which they thought would be barely enough to prevent nuisance in their rivers (reducing it to the terms we use here) would amount to 9,000 cu. ft. per min. for every 100,000 people, or 50% more than Chicago is now pumping. I have proposed in our plan for the disposal of the sewage of Chicago to assume a quantity equal to double the limit in England, or, in other words, 18,000 cu. ft. for every 100,000 inhabitants.

An English "thought" was assumed to require doubling, and someone increased the double by the ninth part thereof, and lo! and behold! the Chicago standard of 20,000 cu. ft. of water per min. for each 100,000 people, resulted.

How will the proposed dilution affect the present conditions at St. Louis? Chicago is now pumping from the Chicago River into the Illinois & Michigan Canal, according to official reports for 1898, an average of 49,900 cu. ft. per min. Accepting this figure, we have the startling fact, that when the flow of the Mississippi past St. Louis is near a minimum, it is but 40 times the amount now pumped from the Chicago River into the Illinois & Michigan Canal at Bridgeport. At a like stage of the Mississippi, when the required minimum flow (of 300,000 cu. ft. per min.) through the canal is realized, the proportion that has traversed at least a part of the Chicago River will be one part in eight.

If we estimate the dry weather volume of sewage as equal to the water supplied, we have approximately 25,000 cu. ft. of sewage per min. discharged by Chicago sewers into the Chicago River, or 50% of the quantity pumped at Bridgeport. When the Sanitary and Ship Canal is in operation and carrying 300,000 cu. ft. per min., at least one-twelfth part of this flow (8⅓%) will be sewage. Applying these estimates, the present minimum flow of the Mississippi at St. Louis is but 80 times the volume of Chicago's sewage. When the Sanitary and Ship Canal is in operation, the proportion will be 1 part in 91.

For the protection and benefit of its own people, the State of Illinois, in the Drainage Act, imposed certain conditions, which are not solely for sanitary reasons, because expected benefits to commerce, navigation and industrial development had much influence with the Legislators.

The conditions and requirements of the Act, pertinent to this discussion, are to be found in Secs. 20 to 27, inclusive, which are as follows:

Sec. 20. (Capacity of Channel or Outlet.) Any channel or outlet constructed under the provisions of this Act, which shall cause the discharge of sewage into or through any river or stream of water beyond or without the limits of the district constructing the same, shall be of sufficient size and capacity to produce a continuous flow of water of at least 200 cu. ft. per min. for each 1,000 of the population of the district drained thereby, and the same shall be kept and maintained of such size and in such condition that the water thereof shall be neither offensive or injurious to the health of any of the people of this State, and before any sewage shall be discharged into such channel or outlet all garbage, dead animals, and parts thereof, and other solids, shall be taken therefrom, and said District shall, at the time any sewage is turned into or through any such channel or channels, turn into such channel or channels not less than 20,000 cu. ft. of water per min. for every 100,000 inhabitants of said District, and shall thereafter maintain the flow of such quantity of water.

Sec. 21. Sanitary District—Failure to comply with Act—Remedy—Penalty.) In case any sanitary district in this State formed under the provisions of this Act, shall introduce sewage into any river or stream of water, or natural or artificial water course, beyond or without the limits of such district, without conforming to the provisions of this Act, or having introduced such sewage into such water course, shall fail to comply with any of the provisions of this Act, an action to enforce compliance shall be brought by the Attorney-General of this State in the Courts of any County wherein such water course is situated, or he may authorize the State's Attorney of any such County to commence and prosecute such action in any such County; provided, that nothing in this section contained shall be construed to prevent the prosecution of any action or proceeding by individuals or bodies corporate or politic against such district; and provided further, that if any individual, or the authorities of any municipal corporation, shall file with the Attorney-General a verified statement, in writing, setting forth wherein said sanitary district has failed to comply with any of the provisions of this Act, it shall be the duty of the Attorney-General forthwith to file in the Supreme Court of this State a petition for mandamus, setting forth wherein said sanitary district has failed to comply with the provisions of this Act, and said Court shall thereupon hear and determine such cause and proceed to enforce compliance with the provisions of this Act, as in other cases of mandamus.

And in order to comply with the provisions of this Act, such sanitary district is hereby authorized and empowered to levy and collect such tax, as an emergency tax, upon the taxable property of such sanitary district as may be necessary to carry into effect any order, judgment of decree of said Court relating to the requisite flowage or water capacity of the channel or outlet and construction, maintenance and operation of movable bridges, as required by this Act.

Sec. 22. (Act—How construed.) Nothing in this Act contained shall be so construed as to constitute a contract or grant between the State of Illinois and any sanitary district formed under its provisions, or to prevent, debar or deprive the State of Illinois from, at any time in the future, altering, amending or repealing this Act, or imposing any conditions, restrictions or requirements other, different or additional to any herein contained upon any sanitary district which may be formed hereunder.

Sec. 23. (Channel—How to be constructed.) If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Desplaines or Illinois rivers, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cu. ft. of water per min., and to be of a depth of not less than 14 ft., and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than 18 ft., such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than 150 ft. at the bottom capable of producing a depth of not less than 18 ft. of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20 000 cu. ft. of water per min. for each 100,000 of the population of such district, at a current of not more than three miles per hour; and if at any time the general government shall improve the Desplaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cu. ft. of water per min., or more, from said channel, and shall provide for the payment of all damages, which any extra flow above 300,000 cu. ft. of water per min. from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall, within one year thereafter, enlarge the entire channel leading into said Desplaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cu. ft. of water per min., with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producting a depth of water not less than 18 ft. throughout said channel, and shall have a width of not less than 160 ft. at the bottom; in case a channel is constructed in the Desplaines River, as contemplated in this section, it shall be carried down the slope between Lockport and Joliet to the pool, commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this Act, may correct, modify and remove obstructions in the Desplaines and Illinois rivers wherever it shall be necessary to do so to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water shall be turned into the said channel. And the Canal Commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois & Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said Canal Commissioners to cause such dam or dams to be removed. This Act shall not be construed to authorize the injury or destruction of existing water-power rights.

Sec. 24. (Channel—When Completed—Control of.) When such channel shall be completed, and the water turned therein, to the amount of 300,000 cu. ft. of water per min., the same is hereby declared a navigable stream, and whenever the general government shall improve the Desplaines and Illinois rivers for navigation, to connect with this channel, said general government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

Sec. 25. (May permit territories outside to drain, etc.) Any district formed hereunder shall have the right to permit territory lying outside its limits and within the same County to drain into and use any channel or drain made by it, upon such payments, terms and conditions as may be mutually agreed upon, and any district formed hereunder is hereby given full power and authority to contract for the right to use any drain or channel which may be made by any other sanitary district, upon such terms as may be mutually agreed upon, and to raise the money called for by any such contract in the same way and to the same extent as such district is authorized to raise money for any other corporate purposes; provided, that where the united flow of any sanitary districts thus co-operating shall pass into any channel constructed within the limits of the County wherein such districts are located, and which passes into the Desplaines or Illinois rivers, such united flow shall in no case and at no time be less than 20,000 cu. ft. of water per min. for each 100,000 of the aggregate of the populations of the districts so co-operating; provided, nothing in this Act shall in any wise be so construed as to diminish, impair or remove any right or rights of any city, village, township or corporation, body politic or individual situated on the Desplaines or Illinois rivers, or their tributaries, and with the valleys of the same, to use the channel for drainage or otherwise not inconsistent with rights of the district constructing the same, as expressed in this Act.

Sec. 26. (When city or village owns water-works, etc.) Whenever in any such sanitary district there shall be a city, incorporated town or village which owns a system of water-works and supplies water from a lake or other source which will be saved and preserved from sewage pollution, by the construction of the main channel, drain, ditch or outlet herein provided for, and the turning of the sewage of such city and district therein, and there shall be in such sanitary district any territory bordering on such city, incorporated town or village within the limits of another city, incorporated town or village, which does not own any system of water-works, at the time of the creation of such sanitary district, then upon application by the corporate authorities of such latter-named city, incorporated town or village, the corporate authorities of such city, incorporated town or village, having such system of water-works, shall furnish water at the boundary line between such municipalities by means of its water-works to the corporate authorities asking for the same in such quantities as may be required to supply consumers within such territory, at no greater price of charge than it charges and collects of consumers within its limits, for water furnished through meters in like large quantities.

Sec. 27. (When channel constructed—Commissioners to be appointed to inspect its work.) If any channel shall be constructed under the provisions of Sec. 23 of this Act it shall be the duty of the trustees of such district, when such channel shall be completed, and before any water or sewage shall be admitted therein, to duly notify, in writing, the Governor of this State of such fact; and the Governor shall thereupon appoint three discreet persons as Commissioners, one of whom shall be a resident of the city of Joliet, or between said city and the city of La Salle, and one a resident of the city of La Salle, or between said city and the city of Peoria, and one a resident of the city of Peoria, or between said city and the mouth of the Illinois River, to inspect said work. The said commissioners shall, within ten days after such appointment, meet at the city of Chicago, and shall appoint a competent civil engineer, and they may employ such other assistance as they may require to expeditiously perform their duties. The said Commission shall take as their datum line for the survey the datum established by the Illinois and Michigan Canal trustees in 1847, and shall make such examination and surveys of Chicago River and of the channel or channels authorized by this Act as shall enable them to ascertain whether said channel is of the character and capacity required by this Act. And in case they shall find the work in all respects in accordance with the provisions of Sec. 23 of this Act, they shall so certify to the Governor, who shall thereupon authorize the water and sewage to be let into said channel. But in case said Commissioners shall find said channel is not constructed in accordance with the provisions of this Act, it shall be their duty to file in any Court of competent jurisdiction, on the chancery side thereof, in their name, as such Commissioners, a bill against said corporation, which bill shall set forth wherein said work is deficient and fails to comply with the provisions of this Act; and said court shall thereupon issue an injunction without bond against said defendant, enjoining and restrain-

ing it from admitting water or sewage into said channel until the final order of the court. And in case said court, upon hearing, shall determine that said channel is not constructed in accordance with the provisions of this Act, said injunction shall be continued until the provisions of this Act shall have been fully complied with.

Such commissioners and engineer shall receive for their services ten dollars per day each, and their reasonable expenses and outlays for the time by them necessarily employed in the discharge of their duties, which shall be paid to them from the State Treasury, and the said sanitary district shall reimburse the State for all expenses and disbursements on account of said commission.

If any channel is constructed under the provisions of this Act, which shall discharge the sewage of a population of more than 300,000 into or through any river beyond or without the limits of the district constructing it, the same shall be constructed in accordance with the provisions of Sec. 23 of this Act, and if any such channel receives its supply of water from any river or channel connecting with Lake Michigan, it shall be construed as receiving its supply of waters from Lake Michigan.

To complete the information concerning the special emergency tax, authorized by Sec. 21, it is necessary to quote:

Sec. 13. The Board of Trustees shall have power to defray the expense of any improvement made by it in the execution of the powers hereby granted to such incorporation by special assessment or by general taxation, or partly by special assessment and partly by general taxation, as they shall by ordinance prescribe. It shall constitute no objection to any special assessment, that the improvement for which the same is levied is partly outside the limits of such incorporation, but no special assessment shall be made upon property situated outside of such sanitary district, and in no case shall any property be assessed more than it will be benefited by the improvement for which the assessment is levied. The proceedings for making, levying, collecting and enforcing of any special assessment, levied hereunder, shall be the same as nearly as may be as is prescribed by Art. 9 of an Act entitled: "An Act to provide for the incorporation of cities and villages," approved April 10, 1872. Whenever in said Act the words "city council" are used, the same shall apply to the Board of Trustees constituted by this Act, and the words applying to the city or its officers in that article shall be held to apply to the corporation hereby created and to its officers.

Sec. 14. When any assessment is made under this Act, the ordinance authorizing such assessment may provide that it be divided into equal annual installments, not more than 20 in number, and fix the amount and time of payment of each installment, and that the installment shall bear interest at a rate not exceeding 6% per annum, payable annually, from the date fixed in said ordinance, and the several installments and interest thereon may be collected and enforced, as they shall become due, in the manner provided for the enforcement of assessments under said Art. 9. No more of any assessment need be returned or certified to the County Collector than will show the amount due and unpaid at the time of such return, and no sale of any parcel of land for any installment of an assessment shall discharge the premises from any subsequent installment of the same or any other assessment. Any one or all of the installments may be paid any time after the assessment is confirmed, with accrued interest, if any, to the date of payment.

Sec. 15. Where any assessment is made payable in installments, the Board of Trustees may issue bonds or certificates not exceeding in amount 80% of the unpaid portion of such assessment at the date of the issue thereof, payable only out of such assessment, and bearing interest, at a rate not exceeding the rate of interest upon the installments of such assessments. The Board of Trustees shall have the right to call in and pay off said bonds or certificates as fast as there is money received into the treasury from the assessment against which the same are issued, and all moneys received upon such assessments shall be applied to the payment of said certificates or bonds until they are fully satisfied.

Although it is required that "the water thereof" (that is, of the constructed channel) "shall be neither offensive nor injurious to the health of any of the people of this State," no requirement, other than dilution to a certain degree, is provided to prevent offense or injury, except that "all garbage, dead animals and parts thereof, and other solids, shall be taken therefrom." Even if the sewage is carried through the constructed channel before it becomes offensive or injurious, offense and injury will result from the conditions developed in the rivers below the constructed channel.

The obligation rests on cities, as on individuals, that each should so use his own, as not to injure another.

The Chicago River under present conditions is a septic tank; the contents, when reaching the Bridgeport pumps, are in an advanced stage of decomposition. Under the operation of the Drainage Canal it is expected that the sewage will reach the Canal within a few hours after its discharge from sewers. The faster it travels in Canal and river, the farther will disease breeding germs be carried.

Quiescence is recognized as being a necessary condition for the natural reduction of sewage; hence the expected more rapid flow in Canal and river will extend the range of danger from sewage pollution to unknown and doubtless considerable distance. If the natural processes, now in operation in the Chicago River, are transferred to the quiet pools of the Desplaines and Illinois rivers, the offensive conditions now existing in the Chicago River will also be transferred.

The Act calls for a continuous flow of not less than 300,000 cu. ft. per min.; to meet this requirement, two things are necessary: First, a channel capable of passing that volume under the prescribed conditions of width, depth and velocity; second, the channel must be furnished with the required volume of water.

The Drainage Act provides for an inspection of the empty channel to ascertain if it has the required character and capacity; but says nothing as to inspection of the way the water is to be brought to the channel.

Officials of the Sanitary District stated that the plans adopted contemplate:

	Cu. ft. per min.
(1) Drawing from the Lake through conduit in Lawrence Ave.	20,000
(2) Sewage delivered into Chicago River and branches at various points from sewers	25,000
(3 Drawing from the Lake through conduit on 39th St.	120,000
(4) Drawing from the Lake through main Chicago River	255,000
Grand total	420,000

This total, if attained, will satisfy the quantity condition for a population of 2,100,000. The present estimated population of Chicago is 1,750,000, of which about 80,000 is not within reach of the Drainage Canal; making this allowance, the immediate requirement will be (for 1,670,000 people) 334,000 cu. ft. of water per min. When the 39th St. conduit is worked to its capacity, the South Branch of Chicago River must carry from Kinzie St. to 31st St., 214,000 cu. ft. per min., in order that the quantity condition may be satisfied for the present population. If the quantity is not furnished, the condition of the Drainage Act will be violated. Sec. 21 of the Drainage Act provides a course of action which will result in preventing further use of the Drainage Canal until the conditions are complied with. The Sanitary District will then be "authorized and empowered to levy and collect such tax, as an emergency tax, as may be necessary to carry into effect any order, judgment or decree of the courts."

Should it be found impracticable to obtain the necessary quantity of water at the present eastern terminus of the Canal, it will be necessary to construct a second channel through "The Sag" to the Calumet River. This second channel, under Sec. 23, must have capacity to carry 300,000 cu. ft. per min., and be of a depth not less than 14 ft. Through this second channel, the 45 sq. miles of territory, known as the Calumet District of Chicago, and not now reached by the Drainage Canal, will be provided with an outlet for sewage. The water supply taken at the 68th St. tunnel may then be relieved from pollution by the sewage of the Calumet District, and the expected inadequacy of the present Canal will be met by a long foreseen, carefully planned and provided for "emergency."

In the Annual Report of the Law Department of Sanitary District for 1897, we find the following:

At the same session of the Legislature the Valley Association people proposed a bill known as the Trowbridge Bill, affording the right of injunction and other drastic measures against the district.

After considerable discussion and numerous conferences, a compromise was effected whereby the district obtained the necessary increase in revenue and the Valley people additional legal relief. As a substitute for all the then pending legislation, a joint bill was prepared amending Sec. 11, so as to extend the 1½% tax levy over the years 1898 and 1899, and providing for swing bridges seven years after water was turned into the main channel. Also Sec. 21 was amended so as to enforce compliance with the terms of the Act by mandamus, and the levy of an emergency tax to carry same into effect.

This compromise bill, after considerable work, finally passed, and became a part of the Sanitary District Act. This legislation afforded the necessary revenue to the district, and made it possible by the law to enforce the provisions of the Act and insure the completion of the great work.

The Act as thus amended contains within itself a remedy which, if enforced, will afford sufficient relief for any emergency that might arise. This will prove not only of great benefit to those living in the Illinois valley, but to the taxpayers and residents of the Sanitary District as well.

The President of the Sanitary District Board of Trustees, in his report of Dec. 6, 1898, says:

The improvement of the great Calumet region is a matter that should not be lost sight of, as well as the improvement of the North Branch of the Chicago River. Both of these very important matters were taken up by me in my Inaugural Message. Since that time the Calumet region has been taken up by the Committee on Federal Relations, with the representative people interested. Several meetings have been held, but up to this time no definite action has resulted.

He further says:

As the work nears completion it will become necessary for the Committee on Federal Relations to make arrangements for an inspection of the channel as provided in the law. Furthermore, it is also incumbent upon this same committe to make provisions for securing from the Federal Government permission for the Sanitary District to turn the water into the Great Drainage Canal.

In his Annual Report, Dec. 15, 1897, the President said:

Another matter for your early consideration is the annexation of, or the bringing into the Sanitary District, the following towns or parts of towns, in order to make the Sanitary District co-extensive and including all of the territory within the jurisdiction of the city of Chicago. The territory needed to make the boundaries of the Sanitary District commensurate with the limits of the city of Chicago consists of three districts: Two on the north known as Rogers Park District and the Norwood Park District, and the third and larger, the Calumet District on the south.* * * The Calumet District extending substantially from 87th to 138th St. and Western Ave. to the Illinois and Indiana State Line, containing about 45 sq. miles.

These towns will eventually receive the benefit of our main channel as future work may be necessary within their boundaries, and we would not be justified in expending any money for auxiliary work therein unless they were part of the Sanitary District.

The officials of the Sanitary District have, therefore, been frank in their statements that the auxiliary work will have to be done, and the amendment of Sec. 21 was intended to enable the Trustees to make a special emergency assessment to pay for it.

The Sanitary District and the city of Chicago each has a bonded debt to the full constitutional limit, but under the special emergency tax provision, a lien, in addition to the regular drainage tax, may be laid upon every piece of property in the Sanitary District to an indefinite amount, and an additional debt incurred, despite constitutional limitation.

The distance from the present canal to the Lake at Calumet by the Sag route is about 27 miles, requiring 23¾ miles of new work. We assume the new work will be similar in character and cost to that done in Secs. F and O, inclusive, of the present Canal. The estimated cost of these sections, having an aggregate length of 7¾ miles, for engineering and construction work, is officially given as $2,762,804.36, and 23¾ miles may be estimated to cost $8,436,000.

When this supplementary channel is provided, the flow in each of the two channels is required by Sec. 23 to be not less than 300,000 cu. ft. per min., but the combined volume of 600,000 cu. ft. per min. cannot be discharged into the Desplaines River until the United States Government shall improve the Desplaines and Illinois rivers and shall provide for the payment of all damages which any extra flow above 300,000 cu. ft. of water per min. may cause to private property.

Plans for the disposal of all the sewage and surface water from the territory occupied by the population centering at Chicago had not been made when the Sanitary and Ship Canal was begun, and they have not yet been worked out. Enormous expenditures will be required if present lines are followed, and we venture to say that the results will not be satisfactory.

We suggest that even now, after the expenditure of over $28,000,000 by the Sanitary District, it would be wise to adopt a method of sewage disposal and to use the canal for the other purposes contemplated in the Act, viz.: To carry off surface water, to afford docks, slips, manufacturing sites with shipping facilities, water power and a navigable waterway.

The total expected cost of the Canal as now planned, including all expenditures, was stated in official reports of the Sanitary District for 1897, at $31,195,488, of which by report for 1898, $28,077,043 has been spent, leaving $3,118,446. Add to this the $8,436,000, estimated above for the emergency work, and we obtain a total of $11,554,446, which, if present plans of Sanitary District were dropped and another plan adopted, would go far towards the construction of a better system. To this sum should be added the contemplated expenditure by the city, for the Lawrence Ave. and 39th St. conduits and for pumping stations to supply the conduits.

It may seem that the Commission is going beyond the range of St. Louis interests in discussing the difficulties at Chicago; but we consider that it will be greatly to the advantage of all concerned, if the abandonment of the plan now proposed can be brought about with the consent of all parties.

To carry out the present plans, additional or amendatory legislation will be necessary. As the case now stands, the use of the Canal can be indefinitely postponed by litigation under the statutes of the State of Illinois, or by failure to obtain the permission of the United States to draw from Lake Michigan the large volume of water contemplated.

The present way of disposing of the sewage of Chicago, through the Illinois & Michigan Canal, is a menace to the city of St. Louis, and the dangers from water-borne diseases will be increased by the operation of the Drainage Canal. St. Louis should take steps to protect its water supply against pollution, not only from Chicago, but from the population in the territory tributary to the Mississippi and Missouri rivers above St. Louis. We must remember that as the population of the country increases the pollution of streams will increase also.

By general law of the United States, all cities must, sooner or later, be prevented from polluting the natural water courses of the country with sewage, and by State or Municipal law be required to prevent, by filtration of water supplies, epidemics of water-borne diseases.

We recommend that the city of St. Louis so shape its course as to meet both of these propositions before the necessity for meeting them is forced on the city by epidemics and drastic measures of general law. The study of these questions should be taken up at once and a policy established for future work which will be in harmony with the inevitable requirements of a rapidly increasing population.

We unhesitatingly express our opinion that the Chicago Drainage Scheme, as now contemplated, is radically wrong, and that the greatest wrong is to the citizens of Chicago and the Sanitary District. The State of Illinois has given its authority to the present plan, and its citizens have suffered, and must continue to suffer, in purse and person, for the insufficiency of the scheme, and especially for the fundamental errors in design. Illinois can and should amend its legislation and require the municipality of Chicago to so dispose of its sewage and to so conduct its municipal affairs, that the entire cost and

expense thereof and the inconvenience resulting therefrom shall be borne entirely by the district relieved.

Before the Drainage Canal can be put in operation, several very important matters must be attended to by the United States Government. Under the conflicting provisions of the Act authorizing the Canal, the volume of water stipulated in the Act cannot be sent through the Desplaines and Illinois rivers until the United States Government shall make certain improvements to these rivers, and provide for the payment of damages to private property, due to overflow, which may result from passing a quantity of water greater than 300,000 cu. ft. per min., through the Drainage Canal.

The United States Government must give its permission to draw water from Lake Michigan before the Canal can be put into operation. This question is one which will require a most careful study, as to the effect on the harbor and shipping interests of Chicago and on the shipping interests of the Great Lakes. Without going into details as to the effect of the continuous draught from Lake Michigan of the amount of water contemplated, it is evident that, with the exception of Lake Superior, the water level of all the Great Lakes, the channels connecting them, harbors and entrances to harbors, will be lowered. This change in level throughout the chain of Great Lakes involves not only the interests of the United States, but of Canada as well.

The fundamental proposition on which the operation of the Chicago Drainage scheme depends has not as yet been acted upon or even considered by the United States Government, whose consent and authority must be obtained before any use can be made of the Canal.

When this matter is considered by the United States authorities, related questions should be considered also, such as: The capacity of the Canal; the way it is proposed to convey water from the Lake to the Canal; the sufficiency of the means provided to control the flow; the ability of the Desplaines and Illinois rivers to receive the increased flow in times of flood; the adjustment of liability for damage; the effect of the required removal by the Sanitary District of the dams at Henry and Copperas creek, upon navigation of the Illinois River and upon the use of the Illinois & Mississippi Canal, now being constructed by the United States; the propriety of allowing cities to pollute the water of interstate rivers with sewage, and last, but not least, the international question of the effect upon the Great Lakes. The present Chicago Drainage scheme presents questions which cannot be finally decided by a municipality, a state, or even by the United States Government. If carried out as planned, it will establish a bad precedent, which vitally concerns every state in the Union. Each state, in the discharge of its duty to its citizens, has a right to be heard in protest.

We recommend that copies of this report be forwarded to the Mayor of Chicago, to the President of the Board of Trustees of the Sanitary District, to the Governors and Legislatures of all the States and to the Illinois Valley Association.

We further recommend that Congress be memorialized on this subject.

In conclusion, we recommend that a copy of this report be forwarded to the President of the United States, with the request that all interested be given an opportunity to be heard before Chicago is permitted to draw water from Lake Michigan.

Respectfully submitted. (Signed by gentlemen named in opening paragraph.)

THE ELEVATOR EQUIPMENT OF THE IVINS SYNDICATE BUILDING, PARK ROW, NEW YORK.

(With two-page plate.)

In Engineering News of October 8, 1896, appeared a description of the foundations and framing of the Ivins Syndicate Building, in New York city, which is famous as the highest office building in the world. At the present time this building is completed, and in process of rental to tenants, and it will not be long before the rush of New York business will invade its 26 floors.

The problem of providing rapid and safe transit to and from the various floors of a building containing some 950 separate offices, accommodating over 4,000 people, and with a stream of people constantly passing in and out amounting very likely to 20,000 or more in a day, involves so many interesting details that a description of its solution is of more than ordinary interest to the engineers. In addition, when it is considered that this large number of passengers must be handled within a very limited time, the difficulty of the problem becomes apparent.

There are three periods during the day when the elevator equipment of any modern office building is taxed to its utmost. In the case of the Ivins Syndicate or Park Row Building, as it is generally called, the 4,000 inhabitants of this vertical town arrive between the hours of 8 and 10 a. m.; they rush out for luncheon, and return between the hours of 12 and 2; and they finally leave for the night between 4.30 and 6 p. m. Add to their number the thousands of people who pass in and out all day on business, and it will be seen that the transit or elevator problem of this great office building is fairly comparable to handling the surface traffic of a good-sized and enterprising city.

The limited space available, the great height of lift, the need of flexibility and considerations of economy of operation, finally resulted in the award of the contract for the entire elevator equipment to the Sprague Electric Co., of New York city.

The full contract included 15 elevators of all sizes, from small dumb-waiters to sidewalk ash hoists of 8,000 lbs. lifting capacity. The machines of most interest, however, are the ten passenger elevators, and one slow speed drum elevator for safes running from the ground floor to the 25th and 26th stories. Fig. 1 gives a first floor plan of the Park Row Building, and affords an idea of the location of all of the elevators. The main passenger cars are seen grouped about in a semicircle in the center of the building, nine in the arc and two in a separate shaft at the side nearest the Park Row entrance. Five of these elevators rise to the 25th floor, a height of 297 ft., and five rise to the 26th floor, with a vertical lift of 308¾ ft. One, intended for safes and heavy freight, runs from the sub-basement to the 25th floor, a lift of 324 ft. 7 ins. The hoisting machinery and counterweights for these elevators are placed in the two triangular spaces behind the elevator shafts. Five machines are placed in each space. A floor is placed under the motors for convenience in examining and cleaning the motors, commutators and other parts. Below this in two well-protected rooms are placed the switchboards, each made up of five controlling panels, one of which is shown by Fig. 12.

As the elevators are alike in all particulars, a description of the details of one will suffice for all.

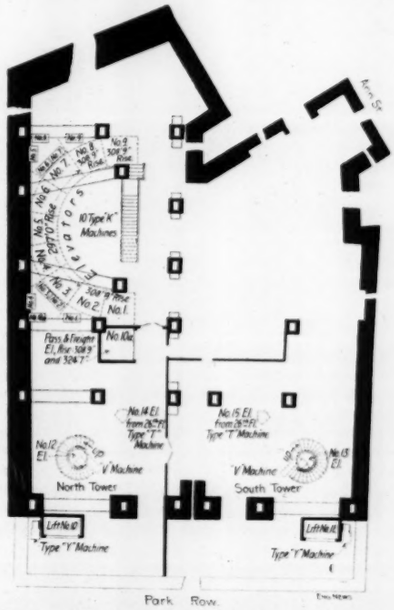


Fig. 1.—Plan Showing Location of the Elevators.

Fig. 2 shows diagrammatically the principle of the elevator operating machinery, and the method of "roping up." Each elevator equipment is complete in itself, and consists of an electric motor with a vertical armature standing 8½ ft. high from the bottom of the armature thrust bearing to the top of the frame; a vertical screw of special design, about 22¾ ft. long; a set of traveling sheaves attached to a nut running on this screw; a corresponding set of fixed sheaves suspended part way up the shaft; a moving counterweight; a pair of counterbalance chains attached to the counterweight, and suitable overhead deflecting sheaves. These are shown diagrammatically in Fig. 2, and to scale in Fig. 3, while the various parts are well illustrated in the following figures. For a full understanding it is best to start with the car cables, where they are attached to the car frame. These are ⅝-in. steel cables, 6 in number, and it will be noticed that they pass up and over the deflecting sheaves at the head of the shaft, and down under the sheaves of the multiplying counterweight, and again up to the framing overhead, to which they are attached. To the bottom of this counterweight, called the moving or traveling counterweight, are attached the four working cables. These are ¾-in. in diameter, and wrap back and forth about the fixed and traveling multiplying sheaves, finally anchoring to the frame of the fixed sheaves. This part of the apparatus may be compared to a block and fall, the end of the rope, being fastened to the counterweight and the screw, to be described later, attached to the block. In Fig. 2 only one pair of operating cables is shown, but in the elevators, as installed, another pair wrap in the opposite direction to balance the strains. This arrangement multiplies any movement of the nut 16 times, and increases the car speed in like ratio. To the bottom of the counterweight are attached two heavy balancing chains made of 1¾-in. round iron with 6-in. links. The purpose of these chains is to balance that portion of the car cables hanging over the overhead deflecting sheaves into the shaft. Examining Fig. 2 it will be apparent that when the car is descending the total weight of cable hanging in the shaft is increasing, and, conversely, when the car ascends the cable weight is constantly decreasing. This introduces a variable load upon the entire equipment which would affect the speed of the car and otherwise interfere with the best operation of the equipment were some means not adopted to equalize or balance the weight of cable. In the majority of elevator systems, where there is a considerable lift, this is compensated for by attaching one end of a chain or chains directly to the bottom of the car and anchoring the other end midway up the shaft. With this arrangement the weight of the chain is added link by link as the cable shortens, or removed link by link in the same way as the length of hanging cable increases with the descent of the car. With the elevators under consideration, the chain is attached to the moving counterweight and, therefore, has only half the length which would be necessary were the other systems employed.

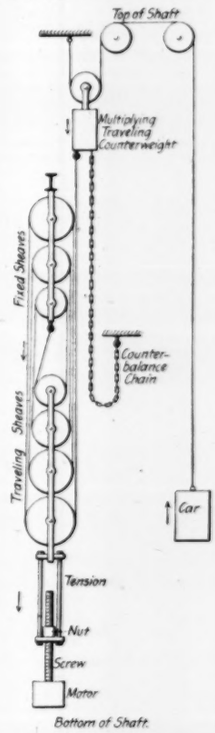


Fig. 2.—Diagram Illustrating the Method of Roping Up.

Fig. 4 shows the details of the counterweight, which is really nothing more than a traveling sheave, the weight required to balance the car in addition to the weight of the cables being very small. Should adjustment be necessary, flat cast-iron slabs can be slipped into the adjustable space and bolted securely in place. Two pairs of ¾-in. operating cables, already mentioned, lead from the multiplying sheaves up and over small bending pulleys at the side of the counterweight, and halfway around an anchor pulley Fig. 4; one pair winding in one direction, the other in the opposite. This pulley has lugs cast on its sides, which, while permitting a certain amount of adjustment, prevent the turning of the pulley should one set

of cables break. These and other details are well shown in the figure.

Fig. 5 illustrates the fixed multiplying sheaves which hang from two heavy 12-in. channels at about the 16th floor. These are arranged tandem, one above the other, to economize space, this design being also safer and more simple than parallel sheaves. Besides the channel iron supports the sheaves are held in a central position by arms bolted to the guide rails of the travbase of the traveling sheaves. The eling multiplying sheaves has a shelf upon which are piled cast-iron weights to adjust the tension upon the cables and the pull required of the operating screw.

Fig. 3.—Elevation Showing General Arrangement of Parts.

The bearings of these multiplying sheaves are made with the greatest care, owing to the necessity of making them narrow, the considerable load per unit area, and to the fact that they are located in a shaft where they are difficult of access, and are in consequence less likely to receive proper attention. Fig. 6 shows the construction of these bearings. It will be noticed that the axle pinches two flat phosphor bronze washers against the side straps, while a third washer is placed between the sheaves. Each sheave is bored to 6¾ ins., and has a hardened and ground steel ring 7-16-in. thick forced into it to form the bearing surface for the steel rollers. The pin or axle is also hardened and ground. Between these faces are placed 28 rollers, 3 ins. long by ½-in. in diameter, made of Howe-Brown steel, tempered as hard as possible. These rollers are held in place by a brass cage which is cast in one piece and machined to be perfectly square. This insures the rollers always keeping parallel to the axis of the pin. To lubricate these bearings, a ⅝-in. hole was drilled into the center of the pin and small offset holes were run to the center of each bearing. The simple device shown in the figure is used to insure the grease reaching both sets of rollers. This consists of a plunger or push rod, just fitting the grease hole, which has a rear portion sliding freely upon the small central rod. To use the device the grease hole is partially filled with some thick grease, the plunger is inserted and pushed back, thus forcing the grease up (B), Fig. 6. The sliding portion (D), is then slipped back, more grease is put in and (D) again pushed back, this time forcing the grease up (C) and into the second bearing. The object in using this form of bearing was to reduce the friction to the smallest possible figure, and at the same time to produce a safe form of bearing, and one that would require the least possible attention. From the bottom of the traveling sheave two 3-in. steel tension rods extend down to the cross-head, which supports the ball-bearing nut, Fig. 9.

At the upper end of the screw, as a matter of precaution, is placed a "Buffer Nut," the details of which are shown in Fig. 7, to prevent injury to the machinery should the nut from any cause travel too far. This buffer consists of a brass sleeve, upon which is slipped a steel collar and 10 rubber washers 7⅞ ins. in diameter by ½-in. thick, separated by 9 steel washers, 0.04-in. in thickness. In case the ball-bearing nut overruns, that is, travels too far, it strikes the buffer nut, and as it is kept from turning with the screw only by the friction between the end of the nut and the crosshead, it jams against the buffer and slips in its socket in the crosshead. The separation of the rubber washers by the steel disks permits a greater compression, as each washer swells in its own compartment. This makes a much smaller and safer buffer than could be obtained with solid rubber.

Following on down the shaft, we next come to the screw and the ball-bearing nut, the two most important parts of the system, and the ones requiring the most care in construction. The screws in these machines, Fig. 8, are 22¾ ft. long, and are 3 ins. in diameter at the base of the thread. The diameter outside the thread is 4 1-16 ins.; the pitch 1¼ ins., and the thickness of the thread ⅝-in. The peculiar form of the thread and the method of feeding the balls to the nut are clearly shown in Fig. 9. This thread is so cut that it has its bearing face upon which the balls roll, Fig. 9, perpendicularly to the axis of the screw. It is made of a forged bar of high carbon steel, having a tensile strength of 130,000 lbs. per sq. in. The screw is not hardened. The nut is rather long and heavy looking, provided at one end with a conical bearing surface, Fig. 9, which rests in a corresponding seat in the crosshead, and is kept from turning with the screw only by the friction between the two faces. This is possible, since the screw is always in tension, holding the nut against the crosshead, and the friction at their point of contact is considerable, and is always more than the friction between the nut, the balls and the screw. Between the threads of the nut and the screw, throughout the whole length of the nut, are ½-in. steel balls, close together, but free to roll along the screw towards one or the other ends of the nut, according to the direction in which the screw is turning. At both ends of the nut are curved conveyor tubes, seen in Fig. 9, which take up the balls as they run out and carry them back to the starting point. In this way the contact between the nut and the screw is always a rolling one, instead of sliding, as is the case with the ordinary nut and screw. These ½-in. steel balls are hardened, and have an average crushing strain of 25,000 lbs., although under service conditions the pressure does not exceed 200 lbs. per ball.

The nut is hardened, and the thread ground in a special machine which uses a small emery wheel revolving at a high rate of speed rather than the usual thread tool. After operating some time it is found that the wearing surface of the unhardened screw becomes exceedingly hard, due to the constant rolling compression to which it is subjected.

It will be noticed in Fig. 9 that the nut consists of two parts, separated along the line C C; the part to the right having a larger and deeper thread. This is the "safety nut," and nominally is out of contact with the screw. Should the working nut fail, from any cause, this nut would come into contact with the screw, hold the car, and put the elevator out of operation, because the friction between the threads of this nut and the screw would be greater than the friction between the end of the nut and the crosshead upon which the nut rests, as already described, and the nut would simply slip like a collar.

The small coil springs, seen in the sectional view of the nut, perform the duty of a slack cable device; that is, a device to prevent the unwinding of the cable should the car become stuck in the shaft while descending. As already explained, the weight of the car suspended from the cables holds the nut against the crosshead, and if for any reason the cables become the least bit slack, the pressure between the nut and the crosshead is reduced and the nut recedes somewhat. Instantly these springs throw the safety nut forward, causing it to engage the thread and jam sufficiently to slip the whole nut against the crosshead, the nut, as in the previous case, revolving with the screw, and the cables, therefore, remain tight.

Continuing down the shaft, the motor brake, thrust bearing and limit stops are next in order, and Fig. 10 affords a general idea of these parts. The method of preventing the slush from the screw working into the upper bearing, and the device to keep oil from leaking from this bearing onto the brake-wheel, governor pulley and the motor armature, is shown in the vertical section. The brake-wheel is 18½ ins. in diameter, with a 7¾-in. face. It is securely keyed to the armature shaft, and is surrounded by a steel band 5½ × ¼-in., lined with wood blocks. Normally the brake band is held free of the pulley by a solenoid magnet, which releases the plunger armature when the motor current is cut off, either at the will of the operator or automatically, when the current supply is interrupted. When released the heavy coil springs clamp the band around nearly the entire circumference of the brake-wheel, bringing the motor to rest very promptly, yet not suddenly enough to jar the machinery.

The motors are 4-pole machines, with two salient and two consequent poles; that is, field coils are used on only two of them. The yoke is of steel, cast to form part of the elevator framing. The armature is of the usual iron-clad, two-path series winding type, using carbon brushes. The field coils have two windings, a series and a shunt, the latter is connected to the car, and is under the control of the car operator.

The armature shaft, as already explained, is securely keyed to the operating screw, and as it is thus always in tension, a substantial thrust bearing is necessary. This bearing is placed at the very bottom of the motor, and is of a unique design, the general features of which are shown in Fig. 10. The armature shaft slips through an ordinary cylindrical sleeve bearing, 6 ins. long, through two hardened and ground steel washers, and has a heavy nut screwed up against a thick steel bearing washer. Between the two hardened washers is placed a bronze plate, shown in Fig. 11, which has a series of rectangular perforations, just wide and long enough to admit small hardened steel cylindrical rollers. These perforations are arranged spirally, so that the entire surfaces of the bearing plates are rolled over. Just below this bearing is another, but smaller, thrust bearing, whose purpose is to support the weight of the armature shaft and screw at such times as the load is removed from the nut. The whole lower bearing, including the roller and end thrust bearing, is surrounded by a cast-iron protecting casing, which

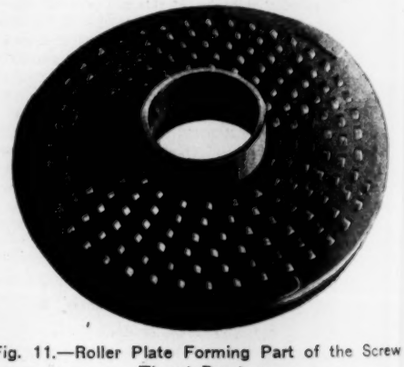


Fig. 11.—Roller Plate Forming Part of the Screw Thrust Bearing.

also serves as an oil cup, and permits the bearings to be flooded at all times with oil, thus insuring cool and free running.

The method of control, commonly known as the Sprague pilot motor control, is extremely simple, and depends upon a small hand switch in the car, conveniently placed for the operator. This switch is connected by means of a flexible cable containing 6 wires, with the operating switchboard in the basement of the building. Each car has one panel of the switchboard, to which the current supply feeders leading from the generating plant and the 6 conductors of the flexible cable are attached. Two of these wires are for the car lights, one the car switch, one for up, one for down, and one for stop. Upon the upper portion of each of these panels, Fig. 12, is bolted a heavy bracket, which supports the "pilot motor," its brake and the contact arm of the starting, resistance. Below this are 4 solenoid magnetic switches, which are called, beginning at the left hand of Fig. 12, the throttle,

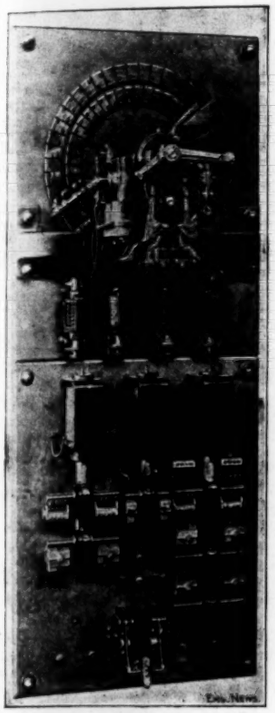


Fig. 12.—View of One Complete Panel, Showing Pilot Motor, Switches, Etc.

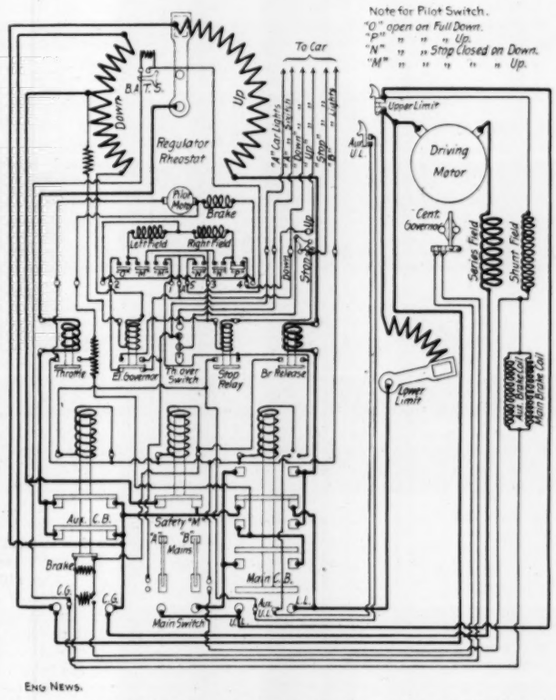


FIG. 13.—DIAGRAM OF CONNECTIONS OF CAR, MOTOR AND CONTROLLER.

electric governor switch, the stop relay and the brake release. Below these are the three automatic main switches known as the auxiliary circuit breaker, the safety and the main circuit breaker. It is impossible in this article to fully describe the operation of these switches, all of which are controlled, either directly or indirectly, from the car. Fig. 13 is a diagram of a complete panel for one elevator, showing the method of connecting up the motor, switches, etc., from the feeder taps to the cable which leads up to the car-controlling switch. This looks somewhat complicated; but if it is examined along with Fig. 12, bearing in mind at the same time that practically all these connections are solidly made at the factory, the system will be seen to be as it is in reality, very simple.

To explain the operation of the automatic part of these elevators, consider one car, since all are alike, and assume that the operator shifts the handle of the switch in the car to the "up" position. This operates the magnetic switches, Fig. 12, and throws the line current into the armature of the main motor, through sufficient resistance to just hold the armature. At the same time the brakes of the main and pilot motor are released and the armature of the pilot motor begins to revolve. On the end of its shaft is a worm which meshes into a worm wheel on the spindle of the rheostat arm. The revolution of the pilot armature gradually sweeps this arm around the contact circle, Fig. 12, and cuts out the armature resistance, thus increasing the speed and torque of the armature of the main motor. The time occupied in this starting can, within certain limits, be controlled by the operator; in other words, he may start as slowly as he pleases, but can never start faster than a certain predetermined safe rate.

To stop the car the operator simply lets go of the switch handle, and instantly the main motor current is cut off, the springs throw the brake into action, and the rheostat arm slowly revolves back to the off position. Should the operator be crowded away from the controller, become careless or frightened, and let go of the switch handle, the car stops instantly and automatically.

When the car descends, the armature of the main motor is first short-circuited, and then the resistance is gradually cut into the armature circuit by the pilot motor, increasing the speed of the car. As it approaches the bottom of the shaft connection is made between the motor and an independent circuit known as the "retarding circuit," and the resistance in the armature circuit is gradually reduced, bringing the car quickly and yet smoothly to rest.

Aside from the safety features of the nut, already described, other safeguards are employed The most important of these are the safety catches placed under the car and rigidly attached to the heavy framing. These are simply lever jaws arranged to clamp the steel car guide-rails when the long arms of the levers are forced apart by wedges driven between them by powerful springs. They are operated by a centrifugal trip governor placed on the car. This governor consists of a small grooved wheel, which is revolved by a rope extending from top to bottom of the shaft where it is fastened. On this wheel are two pawls, normally held against stops by a spring, but which fly out when the adjusted speed is exceeded and trip the safety catches. This form of safety catch was fully described in Engineering News of Nov. 3, 1898, in connection with a description of the Sprague elevators for the Central London Underground Ry. There are also two "limit stops" mounted on the motor frame and arranged to be tripped by suitable triggers on the moving crosshead. These are designed to prevent by possibility the motor overrunning and jamming the car against the top or bottom of the shaft.

In addition to the passenger elevators there are the following smaller or special elevators:

Two Tower Elevators, Type "V."—Capacity, 2,000 lbs. live load; HP. for lifting maximum load, 25; probable average HP. under service, 6, at a speed of 180 ft. per minute.

Two Dumb Waiters, in Towers, Type "T."—Capacity, 200 lbs.; HP. for lifting maximum load, 10; probable average HP. under service, 5, at a speed of 120 ft. per minute.

One Sidewalk Elevator, Type "Y."—Capacity, 2,500 lbs.; HP. for lifting maximum load, 8; probable average HP. under service, 4, at a speed of 50 ft. per minute.

One sidewalk Elevator, Type "Q."—Capacity, 8,000 lbs.; HP. for lifting maximum load, 25; probable HP. under service, 12, at a speed of 50 ft. per minute.

Safe Hoist, Type "W."—Capacity, 8,000 lbs; HP. for lifting maximum load, 25, at a speed of 50 ft. per minute.

The 8,000-lb. sidewalk elevator has a number of interesting features, and in a later issue we will describe it in some detail. The safe hoist elevator, as already mentioned, runs in the same shaft with one of the regular passenger elevators. It is supported by two ⅞-in. steel cables, and employs a standard drum machine with two 44-in. drums, using the double Hindley worm, wormwheels, etc. The single motor is controlled only by a rheostat in the basement, placed near the winding machinery to avoid any chance of collision with the passenger elevator, in whose shaft the safe hoist runs.

Current for operating the 15 elevators is supplied from the engine room of the building where there are three Dick & Church tandem compound horizontal engines, with cylinders 15½ and 17 ins. by 18-in. stroke, each direct connected to a 200-K.-W. Westinghouse generator furnishing 1,665 amperes at 120 volts. There is a smaller cross compound engine, made by the Phoenix Iron Works, Meadville, Pa., with cylinders 10 and 17 ins. by 12-in. stroke direct connected to a Westinghouse 120-volt 250-ampere generator. A 9½ x 12 engine by the same company is direct connected to a small 25-volt generator used to charge the storage battery with which the building is equipped. In addition there is a motor generator which can be used to charge the battery when the main plant is idle, and the engines are running on light uneconomical loads.

Regarding the efficiency and cost of operating the passenger elevators no absolute data can be given, as no tests have as yet been made. It is quite certain, however, that the average running current for the average live load in the car will not exceed 175 amperes at 120 volts. This current is used in hoisting only; none is used while the car is descending, so that the average current per trip will be one-half of the above. The kilowatt hours per car mile are expected not to exceed 3½.

For the drawings and information from which this description has been prepared we are indebted to Mr. Frank J. Sprague, Technical Director of the Sprague Electric Co.; Mr. Charles R. Pratt, Mechanical Engineer, and Mr. G. H. Hill, Electrical Engineer, of the Sprague Company, and Mr. Rasmussen, foreman in charge of construction.

A SECTIONAL THIRD-RAIL ELECTRIC STREET RAILWAY SYSTEM.

A practical test of a type of electric third-rail street railway was made on a 2,000-ft. experimental section of track at Manhattan Beach, New York city, on April 12, in the presence of about 300 street railway officers and electrical engineers. The company exploiting the system has been experimenting for some time and the test mentioned was to exhibit the practical working of its apparatus.

The system is known as the Murphy Safety Third-Rail System, after its inventor, Mr. John McL. Murphy. It belongs to what may be termed the sectional third-rail magnetic switch type and, except for details, is much the same as others of this class.

The principle upon which it is based can be best explained by imagining the ordinary overhead trolley wire brought down to the street surface, and cut into sections of not over 25 ft. in length, which are insulated each from the other and all

from the ground. Then, instead of connecting these sections directly to the feeder cables so that they would have current on at all times, as is the case with the ordinary trolley, automatic switches are inserted between each section and the main feeder. Suitable apparatus is also installed on the car in addition to the regular equipment of motor, controller, etc., to operate these switches as the car advances. It is thus seen that the essential features of the system are:

(1) An insulated third rail, made in sections of from 15 to 25 ft. long, which is placed between the tracks flush with the street surface; (2) a special form of magnetic switch, one being required for each section of the third rail; and (3) a motor-dynamo, storage battery and contact plow for each car. Generators at the power station, car motors, controllers, feeders, etc., are the same as with any form of electric railway.

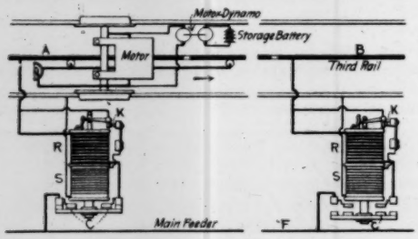


Fig. 1.—Diagram Showing Connections for Two Sections of a Single Track Road.
Safety Third Rail Co., New York City.

The third rail is made of ordinary light T-rail in sections of practically the same length as that of the cars. These sections are placed in a wooden trough about 8 ins. wide and 3 ins. deep, resting on porcelain blocks placed about 3 ft. apart. The space left between the rail and the inside of the trough is then filled in with a special insulating asphalt. These insulated rail sections are then placed in the center of the track, with a space of about 10 ins. between their ends, which is filled with a special brick molded to continue the surface of the rail and to prevent the plow catching. The space between the tracks is then surfaced with asphalt with a sufficient crown to prevent water collecting between the track and conductor rail.

As already stated, the sections of the third rail are each connected to the feeder through automatic switches. Two types of these switches are shown in Fig. 2. The larger one is designed for heavy railway operation, such as would be used if a steam railway were equipped with this system, and has a capacity of 2,000 amperes. The smaller is for ordinary street railway service and has a capacity of about 100 amperes. The switch consists of a suitable bobbin upon which is wound a few turns of heavy wire, forming a series coil (R, Fig. 1), and enough fine wire to form a shunt coil (S) with sufficient resistance to permit the coil to take the line voltage as it is connected or shunted across from the third rail to the track. Inside the solenoid thus formed is an iron armature or plunger which is free to lift or drop under the action of the coils. In series with the fine wire coil is a small spring switch (K) with carbon contacts which are snapped apart when the plunger armature raises, and together when the plunger drops. At the bottom of the movable plunger is a cross arm upon which are mounted two carbon blocks (C) and a U-shaped copper contact composed of strips bent up at their ends so that there is a certain amount of spring or give when they strike the contact plates, hidden behind the guide strips, seen in the figure (Fig. 2).

As stated, each section requires one of these switches, and theoretically the proper place for each switch would be near the section it controls. This arrangement is out of the question for obvious reasons, so that the alternative scheme of bunching several switches is adopted. For example, those necessary for an entire block could be placed in a suitable manhole under the street, in the cellar of an adjacent building, in a weatherproof box placed against the side of a house or in an ornamental post box on the sidewalk.

The connections of the third rail, the magnetic switches, the current-collecting plow and other devices are shown diagrammatically in Fig. 1. Assuming the car to be standing still, in the position shown, with the controller in the off position, it will be seen that both switches A and B are open, so that no current can flow from the feeder (F) to the car. However, the small motor-dynamo placed under the car and connected to a suitable storage battery, is in constant operation during this time furnishing the lights for the car. It is also connected to the car controller, so that when the car is running the motor-dynamo takes current from the line and charges the storage battery. In this way the battery requires nothing more than inspection and nominal repairs after being once installed on the car.

When the controller is turned to the first notch, preparatory to starting the car, a circuit is completed through the track, the third rail and the fine wire or shunt coil of the magnetic switch, and the switch armature or plunger is raised as shown at (A). The main motor current can now pass through the heavy series coil of the switch to the third rail. As the motorman continues to swing the controller handle around, the armature of the switch is held up by the main current until the car runs off this section onto the next section in advance (B), drawing up its switch, while switch (A) is still on. In this way the current practically ceases to pass through (A) and flows through (B), since (B) is the path of least resistance. (A) then opens itself without arcing and the shunt coil is again made ready to pick up the armature should a car stop on that section. Of course, when a car is running, the series coils are the only ones that come into play, the fine wire coils serving only for starting. This is possible because the car has two plows placed far enough apart, so that the front plow spans the idle section and picks up the advance switch.

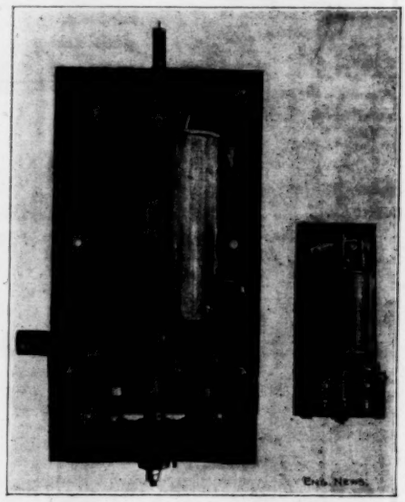


Fig. 2.—Automatic Switches which Control the Sectional Third Rail; Capacity, 100 and 2,000 Amperes.

The advantages claimed for this type of street railway are: that there is no current on the third rail except at points where cars are running and hence there is no danger of shocking pedestrians or horses; there is no slot or conduit to collect water or dirt; there are no poles nor overhead wires; no leakage of current except from the one live section under the car, and the cost of installing is less than the cost of any form of conduit road. Its principal claim to recognition is, however, the fact that each switch is opened only when dead, or, in other words, after the current has practically ceased to flow through it. In consequence, there is absolutely no arc found at the switch contacts. This feature is a most important improvement over previous forms of switch used with railways of this type, most of which open with fairly heavy currents flowing and naturally are subject to the usual troubles accompanying arcing.

Its defects are those inherent to all form of magnetic switch railways and are: the liability of failure of the switch to open after the car has passed, thus leaving the section alive; the liability of switches sticking and not operating at the proper time, resulting from burning out, moisture or defects; the expense of repairs and maintenance, due to the necessity of opening and closing 200 to 250 somewhat complicated switches for every mile traveled by a car. In the case of a 10-mile double track road this would mean perhaps 5,000 switches, and the maintenance of these might prove a considerable item.

The first defect mentioned, that of failure to open after a car has passed, is the most objectionable, for it would result in leaving a bare rail in the street charged with current of high voltage, and certain to give a severe shock to any person who touches it. It seems to us also that this defect is one not unlikely to occur. For example, assume that the track is covered with slush or with mud, or that a heavy rain storm covers the track with water. If a car runs over the track under such conditions a shunt may be established from the conductor rail to the track rail and the current which will flow through the circuit thus established may be sufficient to hold the switch closed after the car has left the section.

It may be possible that the apparatus can be modified to overcome this possibility; if so, it should be done, for even though the leaving of live sections in the track should occur only at rare intervals, its results would give the system a very black eye in the public estimation.

THE CANTILEVER BRIDGE ACROSS THE NIAGARA gorge is to be strengthened in order to provide for the constantly increasing weight of rolling stock. This bridge is owned by the Michigan Central R. R. It was commenced April 15, 1883, and completed Dec. 1, 1883. It was one of the first bridges of the kind built in the United States, and the total length of the bridge proper is 910 ft. It has two cantilever arms, one of which is 375 ft. in length and the other 395 ft. The towers that support these arms rise from abutments located near the water's edge in the gorge. Between the ends of the cantilever arms there is the ordinary suspended truss hung from the ends of the cantilevers, filling the gap and completing the bridge. The height of the deck of the bridge above the water is about 245 ft. The bridge is a double-track structure, but is not open to pedestrians. The improvement which it is now proposed to make to the bridge will consist of the construction of a new stone pier on each side of the river, right between the two present piers, and on this new pier will be erected a bent to carry a new truss under the center of the bridge from end to end. By this means, it is said, the strength of the bridge will be increased 50%. The new piers will be nearly identical with the old, and the legs of the new bent will be vertical, while those of the old are inclined. The steel for the improvement will be furnished by the Detroit Bridge & Iron Works, of Detroit, Mich., and the work will be carried on during the summer, under the direction of W. J. Duncan, Assistant Engineer of the Michigan Central R. R. The piers will be built under the supervision of Charles Patten, of Niagara Falls South, Ontario, who has charge of all the Michigan Central stone work. As there will be a great amount of field work to be done, it is expected that the work will progress slowly. It will be necessary to cut the old iron members in order to place the new work. For some weeks men have been at work on the New York side between the old piers with a diamond drill to ascertain whether or no the currents of the big eddy of the river at that point have in any way undermined the old piers. The foundation was found to be of a boulder formation untouched by current effects or the wash of the river. The space between the piers on the Canadian side has also been stripped, and a diamond drill will be sent down there to ascertain the conditions of the rock. It will probably be early winter before the work is completed, and in the meantime the Michigan Central R. R. will consider what is best to do with the deck of the bridge to prevent the salt water drippings from refrigerator cars falling upon the iron and injuring the structure. It is possible that a new and tight deck will be laid.

ALCOHOL IN BRICKS, for burning purposes, is now being put upon the market in Germany and in New York. The German product, on analyses, shows approximately 62.5% alcohol; 20% residue, almost exclusively animal fat, or soap, and 18% water. It is said that a brick weighing 50 grammes, or 1¾ ozs., will bring one liter of water to the boiling point in 10 minutes. The so-called "Foster Spiritus" is termed "alcolia" in New York, and is said to be made by dissolving "savon amygdalin" in warm alcohol and allowing it to solidify. It hardens again when the light is extinguished.